THE FAMILY CELESTIAL

MILTON ANCRUM SHULER, LL.B.

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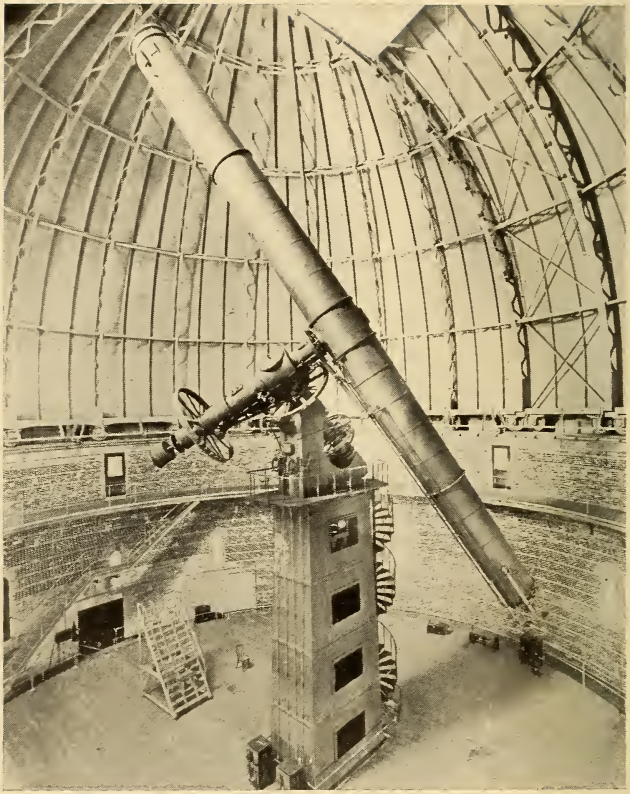

Yerkes Observatory.
(Interior View.)

THE FAMILY CELESTIAL

By

Molton Ancrum Shuler, LL. B.

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Molton Ancrum Shuler

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DEDICATION

In particular, to the bright boys and girls who were pupils in the Monetta High School during the scholastic years 1908-09 and 1909-10, and who manifested such a lively interest in and evinced such a desire for a knowledge of astronomy; and, in general, to the boys and girls of the commonwealth and of the world who may never be able to take a course in astronomy, but who desire to know at least some of the fundamentals and phenomena of this most comprehensive science.

Ye stars! which are the poetry of Heaven!
If in your bright leaves we would read the fate
Of men and empires—'tis to be forgiven,
That, in our aspirations to be great,
Our destinies o'erleap their mortal state,
And claim a kindred with you: for ye are
A beauty and a mystery, and create
In us such love and reverence from afar,
That fortune, fame, power, life, have named themselves a star.

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PREFACE

Statistics show that only a very small percentage of our boys and girls ever take a college course; and many of those who do complete their course never study Astronomy at all. Their time and effort are spent on something else in this great commercial age, and they are not led to comprehend the beauty of Astronomy. If once they were brought to a knowledge of its glory and splendor, in a great many cases they would pursue a study of the science for the sake of culture alone.

Astronomy is one of the most beautiful sciences which it is our pleasure and privilege to study. Nothing else, unless it be Geology alone, touches so many sides of life and so many phases of nature; it is extremely comprehensive—it is a study of the Universe.

The writer of this little volume, when a teacher in the public schools, observed how intensely interested not only the boys and girls in the high-school department, but also those in the lower grades, became when the glory of the heavens was unfolded to them; and this intense interest on their part has led the author to decide to publish the set of short essays which he outlined in talking to his pupils on this subject.

These are for the most part things known for a long time, and expressed again and again; but the writer trusts that the mode of expression used may commend itself to those who read, and that every boy and girl may, therefore, be prompted to learn the story of the Celestial Family. We know of nothing more pleasant to the possessor than having his mind stored with a knowledge of wonderful facts and suitable expressions in which to clothe them. He is thus marvelously aided in conversation, and also in the production of themes in the school room. His outlook on life is changed, and he gazes upon nature and her marvels with eyes of rapture and of gladness.

This little work consists of fifteen short chapters—one on the Sun, Moon, and each of the Planets; one on the Solar System; one on Gravitation, on the Comets, the Shooting Stars; and one on the Suns in Space. The plan follows the general outline of writers on this subject, beginning with the Sun—the center of the system—and proceeding outward, taking up the planets in their regular order with respect to distance from the sun. The chapter on Gravitation is essential to a true understanding of the many intricate problems relating to the actions of the planets, comets, and meteors, and so it is worked in also.

Much study and reading have been given to the preparation of this little work. Every course taken and every book read had something to commend itself to the writer, who is indebted to it for the part given and the thought suggested; but he is most of all under obligation to the works of Sir Robert Ball, and he would recommend to all who may read this little volume that they follow it up with a study of the great English-

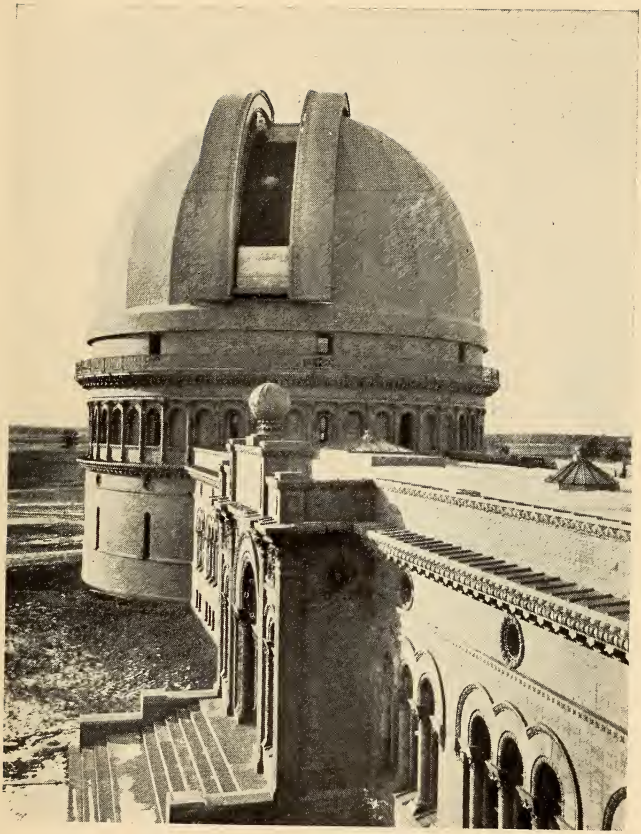
man's works for lay readers. Many expressions and illustrations in this little Book are derived from the works of our eminent contemporary above referred to, and to him the writer tenders his gratitude.

The author is under obligation to the Yerkes Observatory for permission to use their photographs, and he thanks them for the courtesy.

It is the wish of the author that this little volume may find its way into the life of thousands of boys and girls and older people as well, and, cherishing this fond hope, he sends it forth on its mission among the school children of the land.

M. A. S.

Kingstree, S. C.
September 21, 1912.



Yerkes Observatory.
(Exterior View.)

(page 15.)

OUR GREAT LUMINARY

The spacious firmament on high,
With all the blue ethereal sky,
And spangled heavens, a shining frame,
Their great Original proclaim:
Th' unwearied sun, from day to day,
Does his Creator's power display,
And publishes to every land
The work of an Almighty hand.

Nothing better reveals to us the mighty majesty and power of God than a contemplation of the heavens. The great ideas of time, and space, and magnitude, and velocity, and number, and motion, and power claim our attention and elevate us in the scale of being. By contemplating the marvelous glories of the universe, we gain a clearer insight into the will of the Creator, and find exemplified more fully than in any other way the nothingness of man and the superior majesty of God.

Again, when these noble thoughts invest the attention of our minds, we are diverted from the petty feuds and factions of mankind and are made to realize that there is more in life than is indicated by the ripplings on its surface. The deeper current of life's meaning flows as an undertow, reverting and rebounding from every individual and reaching throughout the universe of creation; for no one can live to himself alone. As a mutual attraction is prevalent from one heavenly body to another, so does a mighty force pervade the

entire social universe, acting and reacting upon every member of its system.

We can gain no better idea of the bountiful plenitude of nature than from a consideration of the sun himself—our great and glorious luminary, dispensing light and heat to the encircling worlds and making possible life in some of its multifarious forms. Many people go through life without knowing anything whatever about the distance, relative size, force of gravity, etc., of the sun and his attendant planets and satellites. Of course, nothing is far or near, great or small, heavy or light, dense or rare, unless compared with something else varying from itself in these essential qualities and characteristics. A cat is small when compared with a lion, but large when compared with a mouse. Likewise, the earth is large when compared with the moon, but dwindles into insignificance when contrasted with the enormous volume of the sun.

If we chose a football to represent the sun, we should have to take a grain of sand or a very small shot to show the relative size of the earth. One hundred of these grains placed side by side would extend across the diameter of the football; and the number cubed would give one million, thus indicating that the sun is one million times the size of the earth. In other words, if one million globes the size of the earth were melted down and poured into one, its volume would not equal that of the sun, for in reality the sun is somewhat more than a million times the size of the earth. The moon is about 239,000 miles from the earth, and the

The Sun's Disk.

(I., p. 16.)

diameter of the sun is about 866,000 miles; now, if the sun were placed where the earth is, his volume would extend more than 190,000 miles beyond the orbit of the moon; or, to reverse the position, if the sun were placed where the moon is, his volume would extend more than 190,000 miles on the opposite side of the earth. If a railroad track were laid around the earth, an express train traveling at the rate of sixty miles per hour would pass around the earth in a little more than seventeen days; but at the same rate of speed the train would require five years to engirdle the enormous volume of the sun. These are contemplations which cause us to wonder and to look with increasing interest upon the magnitude of the universe and the majesty of the orbs which revolve in the immensity of space.

The mean distance of the sun from the earth is approximately 93,000,000 miles. This number is so vast that it is impossible for the finite mind to grasp its tremendous magnitude. It can be made more intelligible, however, by an effort to count the number of miles. By allowing the clock to do the work for us, we find that in one hour the clock will make 3,600 ticks, and in twenty-four hours it will make 86,400 ticks. If we divide the number which the clock counts in one day into 93,000,000, we obtain as a result 1,076 days, or a little less than three years for the clock to perform the stupendous task.

If a railway ran from the earth to the sun, we might calculate the period of time that a train, running at the rate of sixty miles per hour, would take to traverse the mighty journey. In one day the train would travel 1,440 miles, and in one year it would cover the tremendous distance of 526,000 miles. This

number divided into 93,000,000 gives as a result nearly 177 years. Truly a long period of time! A man traveling on this great journey could never hope to reach his destination. His great-great grandchildren might live to view the marvelous glories of our splendid luminary. Had the train left the earth when the "Father of his Country" first saw the light, it would just now be ending its stupendous journey. Now, we may ask ourselves the question: How do astronomers measure these vast distances? Since we are considering the sun, we may make an effort to explain how his distance is measured. Two astronomers station themselves as far from each other as possible, which we know is about 8,000 miles (the diameter of the earth), and take observation on the sun. Thus the number of degrees in the angle at each observer as he gazes at the sun is found; from which, knowing the distance between them, they are able to compute the distance of the sun. Eclipses, the transit of Venus across the face of the sun, and other celestial phenomena also, aid in computing the exact distance of the sun; and, as all these methods concur in producing approximate results, the distance from the earth to the sun is a well ascertained quantity.

Some seemingly well informed folk say that astronomy is all guesswork and conjecture, and that they do not credit the so-called wonderful discoveries of the astronomers. To these the scientists may well say that it matters little whether they believe them or not, since it does not make these claims any the less meritorious and true for them to doubt the veracity of the statements made by the observers of the heavens. Astronomy is an exact science: the distances of the

Solar Prominences.

(H., p. 19.)

heavenly bodies are more accurately known than the distances between our great cities. If it were not an exact science, the recurrence of certain celestial phenomena could not be predicted with such unerring mathematical accuracy. Every claim and every statement is proved by mathematical analysis and mathematical exactitude. The recurrence of eclipses, the approach of invisible comets, the prediction of planetary transits, and a multitude of other wonderful phenomena, are wrought out with marvelous skill and exactness. It is indeed wonderful that the mind of man is capable of making such profound calculations and speculations with respect to the great and limitless universe of space lying out beyond the confines of our earth, this "mould of hopes and fears" upon which we spend the moment of time allotted us for the preparation of a nobler existence.

All of us are familiar with the heat of the sun. We know that the beauties of the earth are made possible by the engendering rays of the sun, as they flash across the gulf of space which separates us from that body, and that every spring-tide is made welcome by the resurrection called into existence by this generous heat; then we come to the conclusion that the sun must be so intensely hot that on earth it would be utterly impossible for us in our chemical laboratories or metallurgical establishments to produce heat approximating his in the slightest degree.

Solar prominences dash away from the luminary with a terrific speed, often attaining the elevation of 20,000 miles, while it is recorded that one of these

great tongues of flame extended more than one-third of the sun's diameter from his surface—a distance of 350,000 miles. We must not get the idea that the sun concentrates all of his heat and light upon the earth for our benefit, for our little planet intercepts but the 2,000,000,000th part of his generous rays. All of the heat and light intercepted by the planets and satellites falls as far short of exhausting the supply emitted by the sun as the inhalation of a wren from utilizing the tremendous envelope of atmosphere which surrounds the earth.

There are different ways by which we may perceive the heat of the sun. A common sun-glass, by refracting and concentrating the rays of light and heat, may be used to ignite substances, which is a direct proof of the sun's wonderful heat. Some man of ingenuity and skill has so arranged a sun-glass above the touch-hole of a cannon that, at the moment when the sun reaches the highest point in his daily journey—the meridian of any given place—the heat concentrating through the glass ignites the powder placed in the touch-hole and causes the cannon to be fired. Thus we see that the sun himself, though millions of miles distant, is made to announce the midday hour. By using a peculiar glass globe, which focuses the light and heat, we can construct a tell-tale for the sun. A piece of paper is so arranged that, when the rays of the rising sun passing through the globe strike it, a black streak is burned across the paper. When a cloud intervenes and intercepts the rays, the paper is left unscorched, thus providing the means by which the number of hours of sunshine and of shadow may be determined.

It would be very inconvenient, tiresome, and monotonous to us if we had day or night all the while. What a beautiful and benign provision of nature that gives us alternate hours of light and darkness! If we had day all the time, it would become exceedingly wearisome on account of its unbroken uniformity; for we should then have to arrange our work according to some ill-conditioned schedule. And, on the other hand, if the shades of darkness continued for long and indefinite periods, it would become extremely oppresive and burdensome to us. We should probably find ourselves in a precarious position somewhat like a certain cock in the Arctic regions. After crossing the Arctic Circle, since the sun did not descend below the horizon, but continued to shine with unabated vigor for several months together, the cock, hitherto very punctual in announcing the hour of dawn, knew not when to crow. At times he would take to violent fits of crowing, and later, since his former efforts availed nothing, he would sulk in his gloom and sadness, like Achilles of old, until in sheer desperation he threw himself into the frozen waters of the Northern Ocean.

To account for the recurrence of day and night the ancients made many conjectures. Not knowing that the earth rotates on her axis, as a consequence of which day and night are respectively produced as one side of the earth is brought into the sun's light leaving the other in shadow, some of the ancients said that the sun was an archer god borne in a flaming chariot across the concave of the heavens. Others gave it as their opinion that Vulcan, the god of fire, spent a long period of time in forging a flaming fire-

brand capable of illuminating the terrestrial regions, and that every morning he would throw the sun across the sky and then, with all of his wonderful speed, he would sail around the frozen north to catch in his boat the sun as it fell into the waters of the west. This was a very pretty story; but it was very tiresome work for poor old Vulcan. But how did the ancients account for the difference in the length of the days in summer and in winter? They said that, as the fire-god in summer threw the sun with such terrific force that he would have to struggle with all of his might to get back to the east in time for the next day to begin, these efforts so weakened and exhausted Vulcan that in winter he could throw the sun only a short distance across the heavens. These outbursts of energy on the part of the fire-god accounted for day and night and for the difference in their length in summer and winter.

This was a beautiful theory, but it was altogether inadequate to satisfy the inquiring mind of philosphers and scientists; and we need not be surprised to learn that years and years later the solar system was comprehended in its true significance, with the sun as the central luminary and the earth as an attendant planet. This wonderful discovery on the part of the astronomers changed the whole theory of the universe. Instead of the sun, moon, and stars revolving around the earth as a common center, the stars are suns, and the planets and satellites are simply attendants. If our little sun and his retinue of followers were instantly blotted out of existence, it would make no material difference in the vast universe, and only a little point of light would cease to glow.

The Corona.

(Ill., p. 23.)

Of all the celestial bodies, we owe most, yea everything, to the sun. Were it not for the sun, our little earth would be cold and dark and dreary, an unfit habitation for such beings as the members of the human race. His light and heat make possible the growth of every bud and blossom; the corn develops under the magic touch of his benign influence; the cotton whitens beneath the blue skies as a result of his fostering rays, and the fruits are struck through with juicy ripeness as he causes the breath of summer to pass over the land. The sun's heat raises water from the ocean in the form of vapor, and then precipitates that vapor as rain to refresh the earth and cheer the flowers, to fill our rivers and waft our mighty ships to the sea. The sun's rays beating on the broad expanses of land give existence to the breezes and winds which turn our wind-mills, sail our air-ships, and waft our vessels across the mighty deep. Of course, the atmosphere belongs to the earth, but the heat of the sun sets it in motion and causes it to serve us in turning our machinery and in bearing vapor to the otherwise parching lands.

In prehistoric ages when the earth, as a result of the sun's rays and her own inherent heat, was far more intensely heated than at present, the mighty vegetation of the coal period was produced; and now, while we enjoy the many comforts and conveniences made possible by the numberless uses to which coal is put, we are but enjoying the sunbeams which shone on the earth countless millenniums ago. In the form of coal that heat has slumbered for ages, till we in this later

day summon its activities to our service. Plants and trees in growing appropriate heat, and then give off this heat according to certain chemical agencies and conditions. A piece of wood, when consumed by fire, gives forth perceptive heat; but the same wood, if allowed to decay, emits an identical amount of heat, although given off during such a long interval of time that we are not able to perceive it.

It is the power of the sun stored up in coal and wood that runs our steam engines, turns our factories and cotton mills, and drives our locomotives over the land and our steamers and battleships across the sea. It is the light of the sun stored up in material products that beams from the lights in our cities, making them places of industry and of thrift. Every industry and enterprise on the earth is in some way connected with the potent influence of the sun. And yet the greatest amount of the sun's engery that we are able to appropriate falls as far short of exhausting the boundless supple emitted by that glorious body as the sip of a bird fails to exhaust the volume of some mighty river as it meanders to the sea.

The governments of the earth—and they are to be commended for it— are endeavoring to reserve their forest supply, that future generations may not be deprived of and made to suffer from a loss of the conveniences which result from the bounties of nature; but, so long as the sun continues to shine and supply the earth with light and heat, we shall be cared for; for scientists will so arrange glass mirrors or some other device as to reflect, concentrate, and store up sufficient heating and illuminating energy to operate and manipulate every industrial enterprise existing on

the earth. A few square feet of surface contain sufficient energy in the form of solar heat to propel an engine of colossal proportions. The tides, engendered by the influence of the moon and sun, may also be used as a source of power, greatly increasing the facilities of the human race. The future shall witness the utilization of this hitherto unemployed energy, by which the teeming millions of the earth shall prosper.

As great and important as is the sun, he has many rivals in the infinitude of stars which stud the universe; but these countless suns have very little effect, if any, on the earth and our existence, since they are so far from us that they are not capable of contributing to our necessities. Our own immediate sun, dispensing to us light and heat and supplying our needs and making the earth a place of beauty and of happiness, is the controller of our destinies. To him we look for sustenance, and in him we find our plenitude for the future development which the coming centuries shall witness on this earth. Yet the poet tells us:

"The sun is but a spark of fire,
A transient meteor in the sky;
The soul, immortal as its Sire,
Shall never die."

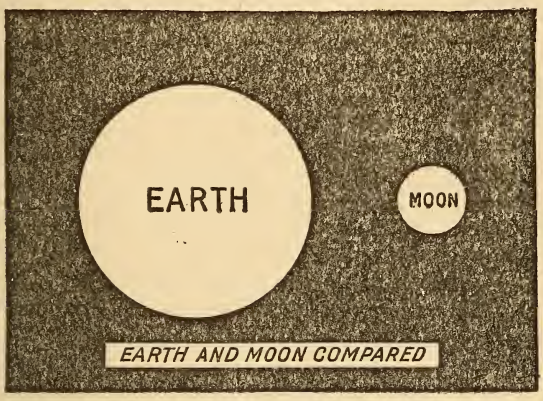
OUR SATELLITE.

Soon as the evening shades prevail,
The moon takes up the wondrous tale,
And, nightly, to the listening earth,
Repeats the story of her birth;
While all the stars that round her burn,
And all the planets in their turn,
Confirm the tidings as they roll,
And spread the news from pole to pole.

Our satellite is about 239,000 miles from the earth, being only the one three hundred and eighty-ninth part of the sun's distance. In comparing the earth and the sun, we found the sun to be many times larger than the earth; but, when we compare the earth and the moon, we find the moon to be many times smaller. If the moon were drawn nearer and nearer to us, however, she would after a while exhibit the appearance of a vast continent stretching out above the earth. We might, figuratively speaking, call the planets sons and daughters of the sun, and the satellites we might name his grand-children. The moon, then, is the earth's daughter and the sun's granddaughter.

At this point it might be well for us to give the beautiful nebular theory, which has been propounded by the astronomers for the purpose of accounting for the singularities and the origin of the solar system. It is believed that in ages vastly remote the planets and their satellites were united with the sun in a

nebulous mass. This mass was diffused throughout a certain portion of space, and parts of it on becoming semi-solid were detached from the main body, the



EARTH AND MOON COMPARED

outermost planets being the first formed. As these masses varied in volume, all being far smaller than the sun, the larger ones were attracted by him and began to swing in their orbits at their relative distances from the central luminary; while the smaller bodies near by were attracted by the larger, and began to whirl around them as satellites. Perhaps millions of these small bodies—fragments—were so far from any of those which we know as planets, that the sun exerted more magnetic force upon them than did the planets; and, therefore, they began to swing in an orbit around the sun, thus failing to become satellites for the attendant planets. For aught we know, these small bodies pursue courses around the sun as true as the mightiest globe in our system. They are too small, many of these

planetoids, to intercept and reflect sufficient sunlight to enable us to see them; but some of the Asteroids, minor planets, may be seen through powerful telescopes.

The planetesimal theory of the formation of the solar system, and of every system in the universe, is based upon the hypothesis that a great nebulous mass was affected with a spiral motion which caused nuclei to form, and about each of these gathered more or less material which solidified in time into a planetary body. It is barely possible that the entire mass may have, by this spiral motion, formed one vast body, and, by contracting and cooling outwardly for ages, the formation of internal gases might have been the result. After being pent up for ages, the gases might have caused a tremendous explosion which sent the nebulous matter in all directions, and this later congealed through the process of cooling into more or less solid forms.

We cannot say for a certainty that the solar system was formed as above described in the so-called nebular and planetesimal theories. Suffice it to say, however, that the system exists in harmonious accord and beauty, controlled by the universal laws of nature and of nature's God. The solemnity of this thought is such that we are led further on in our contemplation of the heavens; and the more we think about the solar system in the present form of its existence, the more are we impressed with its significant beauty and development throughout the ages of the past.

All of these masses emitted from the main body, if either of these theories be correct, were of the same temperature as the sun himself when they began their movements of rotation and revolution; but, since smaller bodies when heated cool much more rapidly

than larger ones, some of these masses have become so cool that they have now ceased to glow from their own inherent heat and shine only by reason of the reflected light from the sun. We can readily illustrate to our mind the difference of time that objects take in cooling, or radiating their heat, if we place a wire and a rod of iron in a furnace and heat them to incandescence: the wire will become cool enough to handle long before the iron ceases to glow.

Just so is it in the case of the planets and satellites with reference to the sun, and to one another also according to their relative magnitudes. These have radiated so much of their heat that they would be invisible if it were not for the light of the sun which they intercept and reflect, thus making it possible for them to shine and be seen. There may be bodies invisible swinging within the confines of the solar system, which we are not able to see because they are so cold that no inherent heat emits light from them, and also because they are so far away that what little sunlight is intercepted by them is so excessively feeble that we are not able to perceive it even with a powerful telescope; but such bodies must be so small that they can exert no appreciable influence upon the visible members of the system. Indeed, the outermost planet yet discovered—Neptune—is invisible to the unaided vision, and his presence was known by mathematical analysis before he was detected by the telescope. If large bodies, other than those known, existed in the solor system in comparatively close proximity to the familiar planets, they could and would be detected and discovered because of their attractive influence on the various members of our system in causing them

to be dilatory or deviatory in their respective movements. Very small meteoric objects are not capable of exerting a perceptive force in this direction; and, therefore, it is impossible for us to tell their whereabouts until they dash into our atmosphere.

In studying the sun, we had occasion to say that he is more than a million times the size of the earth; but, when we begin considering the moon, we find her somewhat less in size than the fiftieth part of the earth and weighing about one-eightieth as much, since her materials are of lighter proportions or are not so compactly held together. The sun, since he has such a tremendous volume, being, as above set forth, over fifty million times that of the moon, is so large that he glows with wonderful heat; but the moon, on the other hand, is so small, comparatively speaking, that she has long since become cold and lifeless. Our little experiment with the wire and rod of iron is thus exemplified on a marvelous scale.

The sun, being one body, does not contain as much radiant surface as would fifty million moons; therefore, it would not require anything like fifty million full moons to furnish us as much light as the sun. It has been estimated that six hundred thousand full moons would equal with their collective brilliancy the amount of light emitted by the sun.

We ask ourselves the question, Why does the moon undergo so many changes, giving us new moon, the quarters, full moon, and the gradual transformation from the dainty crescent to the beautiful disc of the full? These peculiar phases are due to the fact that the moon keeps the same face turned toward us all the time; and, since only one-half of her surface is

Total Eclipse of Moon.

(IV., p. 31.)

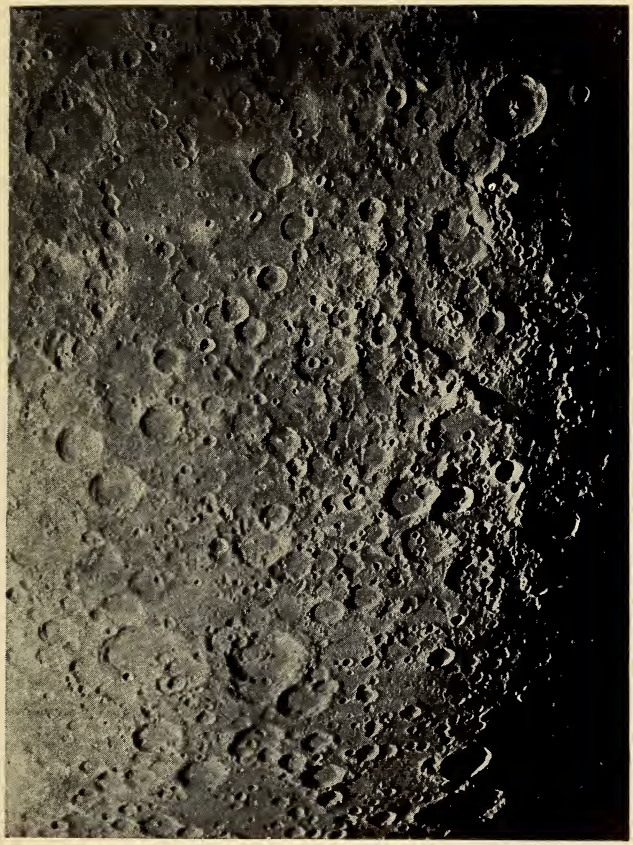
illumined by the light of the sun, she exhibits to us different parts of her bright face, beginning with the new moon and growing daily until the full is reached, at which time the earth, sun, and moon are in an approximately straight line, with the sun and moon on opposite sides of the earth, thus bringing the side of the moon which we see into the full light of the sun.

When the three bodies come in an exact line, one with the other, we have the beautiful phenomenon of a lunar or solar eclippse. The lunar eclipse is produced when the moon enters the earth's shadow as it streams from the sun. These eclipses occur very frequently, and are deeply instructive, since the most interesting phenomena may be observed without the use of a telescope. The solar eclipses are more rare, and occur when the moon passes between the earth and the sun and by so doing obscures his face. During a total eclipse of the sun, twilight reigns for a while and causes a weird feeling to come over the denizens of the earth. We also have partial eclipses and annular eclipses, the latter of which are caused when the moon is farthest from the earth, because then she is unable to obscure the entire disc of the sun, and the beautiful corona or crown emits the wonderful solar prominences.

The moon is the chief instigator of the tides. If she were suddenly stricken from the universe, all the nations of the world would instantly experience much inconvenience in the manipulation of their trade and commerce and in the plying of their fleets and navies,

for the tides would cease to rise and fall. The ships could not go in and out of port on account of shallow water, and traffic and trade and travel would be handicapped. The tidal-wave follows the moon around the earth, and, since the sun also engenders tides to a limited extent, the wave is highest when the sun and moon are together exerting their influence. This occurs both at new moon, when the sun and moon are on the same side of the earth and are working together, and at full moon, when the sun is on one side of the earth and the moon on the other. The reason why the tide is also high in the latter instance is because both the moon and sun are drawing away the water to a certain extent and causing the liquid portion of the earth to become elongated.

When we observe the moon, we see on her surface many dark spots. These are mighty mountains and dark volcanic craters, and they convey a gloomy, dismal impression as we gaze at their long weird shadows and hollow caverns through the telescope. This remarkable instrument, brought into existence by Galilleo and enlarged by many zealous astronomers since his time, enables us to study the celestial bodies with most gratifying results. A good instrument divides the distance by about 1,000; therefore, since the moon is 239,000 miles from the earth, she may be observed and studied at that distance by means of the telescope as well as she might be seen by the unaided eye were she but 240 or 250 miles from us. But in the case of exceedingly remote distances, the telescope can aid us but little. Alpha Centauri, one of the nearest fixed stars, is about 20,000,000,000,000 miles from the earth; if we divide this number by 1,000 we simply cut off



Surface of the Moon.

(V., p. 33.)

one group of figures, and this leaves such a tremendous amount still that the star is but the merest point of light in our most powerful instruments.

In studying the moon with the telescope, astronomers have become more familiar with the configurations of her surface than are the geographers with the dark, unexplored and almost impenetrable jungles of the earth. Every region as large as a township has been mapped out and named. The altitude of the mountains has been measured from the shadows which they cast across the brilliantly illumined surface of the moon's face. These mountains are very high, but not so high as those on the earth. Since there is no water on the moon, and since her mountains extend from the bottom of deep desert plains, we shall in comparing terrestrial mountains with lunar mountains have to consider the distance from the bottom of the ocean to the summit of the mountains as forming a greater elevation than can be found on the moon.

Lunar craters range in width of diameter from a few feet to seventy-eight miles, which last is to be found in the mighty Petavious. Why is it that there are such enormous craters on our satellite? How could the materials be hurled to such a great distance as the thirty-nine miles from the center of the splendid crater just mentioned? We may answer these questions with some degree of accuracy if we bear in mind that the materials on the moon are somewhat different in composition from those on the earth, and that the force of gravitation is reduced to about one-

sixth of what it is on the earth, since the moon is so much smaller than our planet. This lessened gravitation causes greater displacements on our satellite than would be occasioned by the same amount of force on the earth. There may also be an exterior influence which may be responsible for the existence of such grand and magnificent craters on the moon. Meteors, no doubt, dash into the moon as they do into the earth, and, since no atmosphere envelops her as a blanket or shield to trap the meteors and destroy them by friction, they crash into her surface and produce terrible rents and chasms; but it must transcend the realm of probability to say that the meteorites are responsible for the greatest of the lunar craters.

How do we know for an ascertained fact that neither air nor water is present on the moon, thus making life, such as that with which we are familiar, impossible? When the moon is studied through the telescope, no clouds are seen, which in itself is evidence of the fact that water is absent. Sometimes it so happens that apparently the moon passes over a star which may be seen very plainly until the identical moment when it is concealed by the body of the satellite, which proves to us that no atmphere is present; for, if there were an atmosphere, then the luster of the star would be dimmed more and more until the moon completely hid its rays behind her golden form.

In all probability, then, since these two essential elements are absent from the moon, life like ours is impossible. Wonderful as are our telescopes, they fail to show us any form of life on our satellite. Her giant trees, if she should have any, would dwindle away into insignificance, becoming as a twig or a blade

of grass; elephants and mastodons, were they browsing on her plains, would resolve themselves into beetles and grass-hoppers, lost to view in the infinity of distance which separates the observer from his object as he gazes at the moon. Even with all this, still life in some weird form may exist on the moon. When a new land is discovered on the earth, how eagerly people rush forward to possess it and study its wonderfully strange plants and animals! With what zeal and delight they seek precious metals in its glens or rolling sands, and how joyful they seem when the glittering diamond is sparkling from the surface and glistening in the light of the golden morning and radiant as the drop of dew! But, if we could travel on the moon, even though she be considered a dead world, we should, doubtless, become fascinated with the prospect of her scenery and the forms of life which may there exist. Minerals valuable for their utility, and stones precious for their beauty and splendor, might be found in abundant quantities; while peculiar specimens of life, living without water and without air, might occasion the gravest interest and concern and impart to us an insight into the plentiude of nature undreamed of on our mother earth.

If we could live without breathing, it would probably be impossible for us to enjoy a conversation together while touring the country, since there would be no air waves to convey the sound. The silence would be oppressive, and no sweet music or rythmic sounds would greet our weary and noiseless return to our habitations at night-fall. Our homes need not be fitted with glass windows and fireplaces, for without an atmosphere not a breath of air would stir to bring in

dust, and our fires could not burn without a supply of oxygen. Everything would be as silent as death, reminding us of the gloomy fatality of human destiny when guided by the bleak forebodings of atheistic tendencies. Oh that we might learn from nature, from illimitable expanse and boundless infinity, the path of duty which leads us back to love and truth!

THE SOLAR SYSTEM.

What though, in solemn silence, all
Move round the dark terrestrial ball?
What though no real voice nor sound
Amid their radiant orbs be found?
In reason's ear they all rejoice,
And utter forth a glorious voice,
Forever singing as they shine,
"The hand that made us is divine."

Our solar system is composed of the Sun, Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus and Neptune, together with their satellites, the meteors and the comets. In studying the heavens, it is but natural that the sun should first claim our attention. It is by his glorious light that the other members above mentioned glitter like radiant jewels in the sky. If he were blotted out of existence, the planets would cease to twinkle in their lustrous beauty, but the stars which are themselves suns would continue to shine with unabated energy as points of splendor in the sky. When we observe a beautiful planet like Venus or Mars or Jupiter, it is difficult for us to realize that it has no inherent light of its own, but is dependent upon the sun for its power of emanating and transmitting brilliancy throughout the confines of space. Nevertheless, the planets gaze up at their sovereign and reflect his royal majesty.

The ancients were acquainted with five of the planets—Uranus and Neptune being added to the list by the discoveries of modern times—and it was they who gave such significant names, mythologically speak-

ing, to these wandering orbs of light. And this wandering or roving disposition on their part is what led to their being denominated planets; for the word "planet" is derived from a Greek word which means "to wander." Those ancient astronomers, watching their flocks under cloudless Egyptian and Arabian skies, which still furnish unsurpassed facilities for observing the beauties of the heavens, were without the powerful assistance of the telescope; but this, however, did not deprive them of the faculty by which they might gaze upon the shifting panorama of the skies. They mapped down the stars and studied the various constellations. But, after repeating observations, it was noticed that certain stars varied as to position with respect to other stars, and to these the ancients applied the name planets, meaning wanderers.

To those astronomers and philosphers of the ancient time must be given the credit for a large amount of knowledge which is the heritage of our own day; for astronomy is as old as the human race, and our present wonderful enlightenment on this the most comprehensive of all the sciences is but the climax of their achievement. We marvel at the simple faith of these philosphers, as they contemplate the superior majesty of the Creator's handiwork and associate everything glorious and beautiful with the purity of the stars; for, as sings the poet,

"Ye are a beauty and a mystery, and create
In us such love and reverence from afar
That fortune, fame, power, life, have named themselves a star."

Ancient writers frequently mention the stars in singing the praise of the Controller of the universe. Biblical writers, inspired by the divine Spirit, sing His praise in notes of beauty and harmony, as does the psalmist when he says: "The heavens declare the glory of God; and the firmament sheweth His handiwork." And, again, the purifying power of the Redeemer and the kindling radiance of His majesty are made significant in the revelation of that lonely man on the bleak and barren Isle of Patmos, as he gives us the words of his Sovereign and of ours: "I am the bright and morning Star."

In our day of marked enlightenment and accomplished achievement, we are prone to look lightly upon the apparent ignorance of our ancient forefathers, and fail to give them due credit for their splendid part in laying the basic foundation of the superb intellectual edifice of the present epoch. These peoples of the historic morning planted the germs of astronomy, geometry, chemistry, and medicine, which later, under the fostering influence of the ages, developed into the well-known sciences of this later day. What should now be the condition of civilization had not these pioneers at early dawn gone forth, making discoveries in the realms of nature? A mantle of darkness and ignorance would be spread above us, and we should be crying for the light with pleading eyes through the shadows; man would be

"An infant crying in the night,
An infant crying for the light,
And with no language but a cry."

Let us laud the memory of those who, in ages inconceivably remote, when the day was just dawning and the mists were rolling themselves from the horizen, laid the foundation of our intellectual pyramid, which, throughout the ages, the race has erected and climbed until the mind, majestic in its strength, stands erect upon its star-crowned summit, gazing upon the grandeur of the universe, "self-clothed with the prescience of a god."

Observe for one moment what celestial significance was attached to the planets by the ancients as they named them for their gods, thus indicating that the stars of light must be held in close association with the heavenly divinities having their homes far above the airy regions of the earth. It seems that Rome, the mistress of the ancient world, has caused the names of her deities to become attached to the planets, and this shows what a high conception of royal dignity was prevalent among the people of that pagan nation. Jupiter, the largest planet in our system, bears the name of the father of gods and men, controlling their destinies and championing their cause; while Venus, the brightest of the planets, is called after the famous goddess of beauty and of love, complicating a destiny divine with human fatality and giving the race the object of its life. Mars, the ruddy planet, takes his name from the god of war, the art of which was a favorite pastime among the peoples inhabiting the regions around the "cradle of civilization," as the Mediterranean has been aptly called. This art of strife has not yet entirely disappeared from our earth, but, although it has echoed down the ages from the remotest antiquity, we hope that in the future all disputes shall

be settled by arbitration and not by a resort to arms: that international brotherhood shall reign supreme; and, instead of drums rallying men for battle and for death, they may call heroes to a jubilee of peace. Then shall we draw the sword Excalibur from its sheath and fling it far out into the sea, rejoicing that it is gone forever. Mercury, the planet nearest to the sun, takes his appellation from the god of merchandise and eloquence, the wing-footed herald of the celestials; while Saturn, the planet with the rings, is named after the ancient Roman god of agriculture, who was the father of Jupiter and ruled in the golden age.

In a far later day, when the other two mighty orbs were added to our system, a controversy arose as to what they should be called. At last, it was decided that, as the other planets bear mythological names, it was but fitting and proper that these should also be named after the gods of the ancient epoch; therefore, Sir William Herschel's great planet was named Uranus, who was the father of Chronos the Greek god Time; and the outermost planet yet discovered was given the appellation of Neptune, god of the deep. This last is significant, since Neptune is plunged so far into the depths of space that he guards the outer boundary of the spendid solar system with as much unpretentious dignity and complacency as that with which the ancient god ruled over the sea.

Mercury is the nearest planet to the sun, being about 36,000,000 miles from the source of heat and light. His diameter is about 3,030 miles, and he makes his journey around the sun in 88 days, which period of time constitutes one year for that body. It is rather difficult to see this planet, though sometimes he lingers

above the horizon long enough to be seen after the sun, whose enveloping rays shield him from our vision for the greater part of the time, since he attends his sovereign so closely, has gone to light the people at the antipodean side of the earth.

THE PLANETS COMPARED

The next planetary circle described around the sun is followed by Venus, the twin sister of the earth and the brightest gem that glitters in the firmament. Often in broad daylight she may be seen sparkling as a jewel in the skies. Her distance from the sun is about 67,000,000 miles, and she makes a complete revolution around her circuit in 225 days. The length of her

diameter is 7,700 miles, a little more than two hundred miles less than the diameter of our planet. Venus is a most interesting body, and it fills us with delight to study her and contemplate her beauty as she twinkles in the blue azure of the sky.

Next after Venus comes the Earth, with a mean distance from the sun of about 93,000,000 miles. Her diameter is 7,918 miles, and she makes a complete circuit around the central luminary in a little more than 365 days, which is the length of our year. We are great travelers, making more than a million miles daily to cover the journey allotted us each year. If we wish to find the diameter of the earth's orbit around the sun, we simply double the distance from ourselves to that body and obtain as a result 186,000,000 miles; now, if we desire to obtain the distance of our annual journey, we multiply the above number by the ratio which the circumference bears to the diameter of a circle, and obtain as a result the tremendous number of over 584,000,000 miles. We must cover eighteen miles per second if we complete the journey in the time required. The earth moves over one thousand times as fast as an express train and nearly one hundred times as fast as a rifle bullet. What a speed tremendous! And yet, when we observe it in its true phase of comparison, we find it to be a very mediocre rate. An express train or a great line steamer will advance its length in a few seconds, whereas the earth requires upwards of eight minutes to pass over the distance of her diameter.

Next after the earth comes the ruddy planet, Mars, with a mean distance from the sun of 141,000,000 miles. His diameter is 4,230 miles, and he makes his

orbital journey in 687 days. Mars has two beautiful satellites, Phobus and Deimos, who attend him at all times, ever ministering to the necessities of their chieftain.

Jupiter, the largest of the planets, whose volume exceeds that of all the others combined, is 483,000,000 miles from the sun and has a diameter of 86,500 miles. It takes Jupiter about twelve of our years to complete his orbital journey around the sun. He has an interesting and instructive system of satellites, eight in number, which follow him on his untiring journeys through the heavens. These satellites are designated by numbers, instead of by names, by most of the astronomers. It was by observing these satellites in eclipse that the velocity of light was discovered. This in itself was one of the most momentous discoveries which the mind of man has yet made, because it was fraught with so much that was and is essential to a true comprehension of the universe in estimating otherwise almost incalculable distances.

Following Jupiter in the order of the solar system comes Saturn. His mean diameter is about 71,000 miles and his mean distance from the sun is 886,000,000 miles. It requires Saturn twenty-nine and one-half years to make his journey around the sun. He has ten satellites, and they, as those of the other planets named, bear classical appellations—Mimas, Enceladus, Tethys, Dione, Rhea, Titan, Hyperion, Iapetus, Phoebe, and Themis. Saturn is one of the most interesting of the heavenly bodies, which fact is accounted for when we study the peculiar system of rings by which he is surrounded. These rings extend far from his surface, thus presenting that

singular appearance which makes him one of the most marvelous and striking of telescopic objects.

By doubling Saturn's distance from the sun, we reach the orbit of the planet Uranus. The mean distance of this body from his sovereign is 1,782,000,000 miles, and his mean diameter is 31,900 miles. It requires him eighty-four of our years to make a complete revolution around the sun. The lifetime of one of our oldest men would be just enough to span one year on the planet Uranus. He is attended by a beautiful system of satellites, four in number. They bear the significant names of Ariel, Umbriel, Titania, and Oberon.

As the boundary of the solar system we have the planet Neptune. His mean distance from the central luminary is 2,792,000,000 miles—truly a great distance; for, in fact, he is so far away that he is beyond the range of unaided vision. His mean diameter is 34,800 miles, and he completes his voyage around the sun in one hundred and sixty-five of our years. Two reasons may be assigned why the outer planets require so much more time to make one revolution than the inner planets: they have a far greater distance to traverse; and, since they are so far from the sun, his attractive influence exerted upon them is necessarily lessened to such an extent that they move very slowly along their orbital path. So far, only one satellite has been discovered in attendance upon Neptune, though others may be present.

Besides the various planets and their satellites, there are several showers of shooting stars and a number of comets which also belong to the great family of the sun. Indeed, the solar system is a wonderful and

glorious organization of unique individuals, each held in his proper place with respect to the others by the great law of universal gravitation, which pervades the immensity of space. We find out daily more and more about the great laws of nature and of God, as our minds struggle from darkness and slavery back to the light and liberty of the Creator from Whom they came. Education is simply a struggle to be set free from the fetters of ignorance; it is the ascension of the mountain of truth.

THE LAW OF GRAVITATION.

Like the Chaldean, he could watch the stars,
  Till he had peopled them with beings bright
As their own beams; and earth, and earth-born jars,
  And human frailties, were forgotten quite:
Could he have kept his spirit to that flight,
  He had been happy; but this clay will sink
Its spark immortal, envying it the light
  To which it mounts, as if to break the link
That keeps us from yon heaven which woos us to its brink.

One of the greatest discoveries relative to a thorough understanding and full comprehension of the study of astronomy was that evolved by Sir Isaac Newton, the great English mathematician. This discovery is nothing more or less than the great law of universal gravitation, which shall now engage our attention.

Doubtless we are all familiar with the properties of those little bodies called magnets. Natural magnets are pieces of a kind of iron ore called lodestone; this metal was discovered years ago near the city Magnesia, in Asia Minor, from which circumstance it received its name. Artificial magnets are readily made by rubbing a natural magnet with a piece of tempered steel, or by charging the bar of steel with currents of electricity.

Magnets will not attract any and every substance; iron, steel, nickel and cobalt are the bodies upon which they exert their influence. The force of attraction is felt even though certain substances like glass or paper intervene, and the magnet is as true to its affinities in

the common realm as the needle is to the pole in its more scientific application.

The earth and all the planets and their satellites, the sun and all the numberless stars in the firmament, are magnets of various sizes and forces, attracted and attracting throughout the infinity of space. The suns attract the planets, the planets attract the satellites; a mutual action and reaction by which each influences and is influenced by the other. The essential point to be kept in mind about this force of gravitation is that it never entirely ceases, no matter how far we leave the body under consideration. True it decreases with the distance, but its force always exists with an ever lessening ratio throughout the entire universe.

Let us consider the earth for a few moments, and see if we can understand something about the force of gravity. Nothing is more familiar than the fact that, when a stone or any object whatever (unless sustained by the atmosphere) is dropped, it will fall to the ground. The occurrence is seemingly so commonplace that no one at first thinks it worthy of consideration. We are surprised when we see the iron or steel drawn to the magnet; and yet the attraction of the earth for the falling stone is quite as interesting a phenomenon as the force of magnetism, and it is exhibited on a far grander scale, since the force of gravitation is significant throughout the universe.

If we stand upon an elevation and drop a stone to the ground, we find that it will fall about sixteen feet the first second of its descent. This is caused by the force of attraction exerted by the earth. If we use many substances of various sizes and weights, we find that they will all fall sixteen feet the first second

and strike the ground at the same moment if they are released together. The same is true of cotton or a piece of paper or any light substance, if it is placed upon some object which will clear the atmosphere away and free the body of its sustaining influence. We may try these experiments anywhere on the earth's surface near the sea level, and we shall find that the results are approximately the same in every instance. But suppose that we should climb a very high mountain or make a still higher ascent in a ballon; would the earth attract the stone as readily as at the surface? Assuredly she would attract the stone, but that object would require a little longer period to fall through the space of sixteen feet than it did at the surface. The difference of time in falling would be very little indeed, yet it might be computed.

Suppose that some traveler were endowed with the means whereby he might breathe and soar far beyond the outer regions of the atmosphere until he had attained the altitude of nearly a quarter of a million miles above the earth. How would the earth appear from that stupendous distance? The outlines of towns and cities would have vanished from view, and the traveler should see instead the continents and the oceans so far as this were possible through the intervening clouds. But would the force of gravity for the stone still exist? Sir Isaac Newton has demonstrated to us that it would exist still, but in intensity greatly lessened. The stone is released from the balloon by our traveler as he is suspended far above the earth, but, instead of falling with the velocity of sixteen feet for the initial second, it too seems to be suspended in space and takes a minute to pass through the same distance

that at the surface it traverses in one second. Naturally we marvel at this slow rate of speed, but, nevertheless, the falling body, gradually acquiring more and more velocity, rushes onward over its long journey of a quarter of a million miles to the earth.

We, of course, say that an experiment so daring as this could not possibly be made, which is materially true. But Newton conceived the grand idea of using the moon herself to prove the existence of gravity at the distance of her orbit from the earth. Her deflection toward the earth may be calculated, which gives a measure of the earth's attractive power. She is ever falling toward our planet, but, since both are in motion, neither having started from a position of rest, the moon is ever held approximately the same distance from the earth, following in an orbital path around that body.

The gravitation of the earth is a force which extends throughout the immensity of space. The more distant the body, the weaker does this force become; and here, by pondering on this thought, was to be found the idea from which Newton evolved his immortal discovery as to the intensity of gravitation and the law according to which that intensity decreases. We have shown that at the distance of the moon—239,000 miles away—a body requires one minute to fall through the same space that it traverses in a second near the earth's surface. This is conclusive evidence of the fact that the attractive power of the earth, by which she draws all bodies toward her center, becomes weaker at a distance. This is but a parallel case of the law according to which the brilliancy of light decreases with the increase of the distance. Thus are we enabled to state

the law of gravitation in terms which assert that the intensity of this force varies inversely as the square of the distance.

As an elucidation of this otherwise abstruse problem, let us suppose that a body were elevated nearly 4,000 miles above the surface of the earth, so as to be twice the distance from her center as when lying on or near her surface. Now from the law above stated, since the distance is twice as great, the intensity of the attraction varying inversely as the square of the distance, the force of gravity exerted at that height is only one-fourth of what it is when the body lies on the ground. If we drop the body at the distance above indicated, instead of falling sixteen feet in the initial second, it will fall only four feet, which is just one-fourth of the distance which it passes over when near the earth's surface.

Now, if we ascend twice the above distance, so as to be three times the earth's radius from her center, the force of gravity will be just one-ninth of what it is down at the surface. Again, if we treble the first distance, so as to be four times the length of the radius from the earth's center, the force of gravity will be reduced to the one-sixteenth part of what it is at the surface; and so on until we reach the orbit of the moon, 239,000 miles away, which is about sixty times the earth's radius, where the force of gravity will be the one-thirty-six hundredth part of its surface attraction, which is the reciprocal of sixty squared. A body weighing 3,600 pounds on the earth's surface would, if carried to the orbit of the moon, weigh only one pound.

But, after we reach this great distance, does the

force of gravity cease? Astronomy teaches us that the attraction of gravitation, its intensity ever decreasing, is capable of bridging the most profound gulfs of infinite space. We have simply indicated the attractive force of the earth. But the law of gravitation states that "every body in the universe attracts every other body with a force which varies inversely as the square of the distance." There is an attractive force, then, which extends throughout infinity, by which every body in space influences and is influenced by every other body. This is the wonderful law by which the astronomers have unraveled the mysterious and complicated movements of the planets, anticipated the telescope, and felt the existence of bodies before they have been averred by ocular demonstration—we see by the imagination, by intellect, and by a combination of nature's laws.

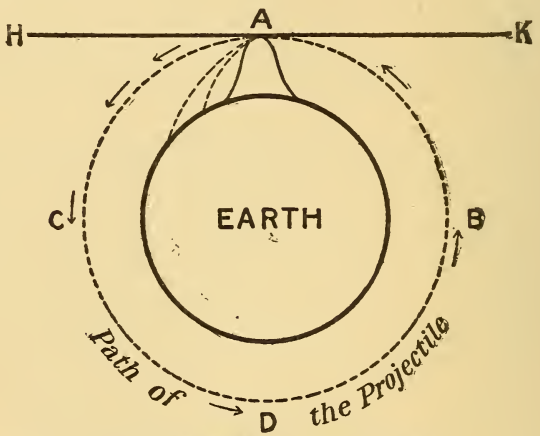
If the earth attracts the moon and the moon attracts the earth, why do they not rush together with terrific force? Since the sun attracts all the planets and their satellites, why do they all not rush together with a frightful collision and thus weld the entire system into one great globe? If all the numberless hosts of stars attract one another, why do they not all draw to a common center, weld the material universe into a massive nucleus, and annihilate the mighty grandeur of creation?

Had the sun and planets and satellites been placed initially at rest, they would have been drawn to the sun and welded into a solid mass as a result of their mutual attraction, thus annihilating the system. But, since all these bodies are in perpetual motion, they are able to resist the force of attraction in such a way as

not to be drawn by it to total destruction. That there may be no misunderstanding about the attractive force of gravity, astronomers furnish a graphic illustration which enables us to see how the earth and moon are made to preserve their proper relation to each other, so far as the force of gravitation is concerned, and this course of reasoning applies also to the primaries or centers of the numberless systems throughout infinite space.

To comprehend this theory fully, we shall imagine that an exceedingly high mountain, with a powerful cannon on its summit, is located on the earth. If the cannon were fired with a moderate charge of powder, the projectile would follow along a curved line until gravity had drawn it to the earth far toward the base of the mountain. If a heavier charge of powder were used, the projectile would follow a more outward path and fall still father away from the mountain; while, if we employ a cannon far more powerful than the massive guns of our citadels and battleships, and powder many times stronger than that of our smokeless type, the velocity of the projectile would be several miles per second, and, instead of falling to the earth, it would follow such a path as that described by the arc A C, ever remaining the same distance above the earth, though still curving, as every projectile must curve under the attractive force of gravity, from the horizontal line in which it moved at the moment of its discharge from the cannon on the mountain. Arriving at the point marked C, it would still be the same height above the earth and its speed would not be abated in the least; therefore, it would continue on until it described a complete circle around the earth;

and now, if we could remove the mountain and the cannon, "we should then have a body revolving forever around the earth in consequence of the attraction of gravitation."



How The Moon Revolves

For an understanding of the subject here involved, we may imagine the moon to have been fired from a mighty cannon stationed nearly a quarter of a million miles above the earth. Of course, this item of distance is contrary to the tidal theory, which declares that the earth and moon were at one time in direct or almost direct contact with each other, since both evolved from the same initial and original mass; but for the present purpose this thought need not concern us, and we may consider the moon as a vast projectile sweeping around the earth, preserving its velocity and continuing indefinitely with respect to its attitude toward the earth

and the attractive force exerted by that body. We are not making the assertion that the moon was fired from some mighty cannon; we are simply showing that she moves in her orbit as if she had thus started on her ceaseless journeying around the earth. Now, just as the moon revolves around the earth, so does the earth revolve around the sun, the illustration showing us that "a circular or nearly circular motion harmonizes with the conception of the law of universal gravitation."

In considering the force of gravitation, we are accustomed to regard it as of stupendous magnitude, since such vast bodies as the earth and moon are controlled by its mighty power. No doubt the actual force which retains these massive bodies in their respective paths around their primaries is of vast intensity; but this is due to the fact that gravitation is in such cases considered in connection with gigantic bodies, as the intensity is almost imperceptible unless one or both of the attracting spheres are of exceedingly great proportions.

We are told by the astronomers* that, if we desire to conceive the force of gravitation as one of measurable intensity, we must employ in our imagination two ponderous globes, composed each of 417,000 tons of cast iron, and, if solid, measuring about fifty-three yards in diameter. A distance of one mile must separate these globes. Each globe attracts the other by the force of gravitation, even though buildings or barriers of every sort and size intervene. This inter-penetrating force may be readily conceived by observing how easily light passes through glass, and then by

*The illustration is that of Sir Robert Ball.

comparing this phenomenon with that of the force of gravity as it exerts itself in spite of all impediments and obstacles. These globes so placed will, according to the law of gravitation, attract each other; but, even with their massive volume, the intensity of their mutual attraction is but the pressure of a single pound. If they were so arranged that friction should be neutralized, the globes would then, by following the impulse of their mutual attraction, begin to come together, with such slow velocity, however, that several days would elapse before they should be in direct proximity one with the other.

The chief thought to consider with respect to this phase of the study of the force of gravitation is that, although we gave the illustration by mentioning globes of cast iron, it matters not of what substance the globes are composed, as the attractive power remains the same so long as the masses remain unaltered, even though the bodies be composed of any metal whatever, or of wood or stone, of water or air. Herein lies the difference, then, between the force of gravity exerted by any and every body and the force of magnetic attraction exerted only by such bodies as those possessing the qualities and characteristics of lodestone.

We have alluded to the fact that the moon travels around the earth in a path which approaches a circle, and that the earth makes her annual journey around the sun in an orbit which is approximately circular. Now the same is more or less true of all the planets. Therefore, it would not be the part of wisdom to dismiss this important topic in the study without showing in what way the orbital paths deviate from the true circle.

If these bodies revolved around their primary in a perfectly circular orbit, with the sun at the center, the radii of the several orbits would remain constant instead of approximately so; for, when accurate observations are made, it is found that the distance from any planet to the sun does not remain absolutely constant, although the circumstances vary somewhat with each of the planets, since the paths of some approach more nearly to exact circles than do those of others.

The theory of circular orbits possesses such beautiful symmetry that we find ourselves endeavoring to propound some means by which we may account for the fluctuations of planetary distances from the sun and still not dispense with the use of the circle. If we supposed that the sun did not occupy the center of the circle, might we not readily see that the radii of the several planetary orbits must necessarily fluctuate, and that the sun would be nearer at one period of the planet's annual journey than he would be at another as a result of his not occupying the true and exact center? Such a system of circles placed around the sun would explain, to a certain degree, the variations in planetary departure from a constant distance from the sun; for the more eccentric his position, the more would the distance from the luminary fluctuate as the planets traversed one part of their orbit and then another. But this explanation did not suffice to satisfy the thoughtful minds of the astronomers. They must have exact, and not approximate, results. So the planets are studied very minutely, their radii shifted hither and thither and adjusted with greater accuracy, until at last it is discovered that such discrepancies arise that it is impossible to reconcile the position

which these bodies now occupy with the position which they would occupy if they moved in exact circles.

Now, if the planets do not move in exact circles, what sort of orbits do they follow? This problem confronted Kepler, the eminent German astronomer, who immortalized his worthy name by propounding a solution for it. By dint of study and application, he discovered that the planets do not traverse exact circles, but describe ellipses more or less elongated, some closely approximating circles and others departing therefrom with considerable eccentricity. Probably this discovery of the true shape of the planetary orbits is one of the most conspicuous events ever demonstrated in the history of any branch of science, for it marks an initial epoch in the conception of the solar system.

From the dawn of history, mathematicians had been familiar with the geometric figure which we call the ellipse; but it seems that this singular figure could not be utilized for any special purpose, although scientists wondered and experimented as to what use it might be put, when all at once it was announced by Kepler that the ellipse is concident and identical with the highways of the universe. Thus, instead of following truly circular orbits, the heavenly bodies traverse elliptic curves, which are more or less eccentric according to the position of the foci. If the foci are widely separated, the ellipse will be greatly elongated; but, if the foci are placed nearer and nearer together, the resultant figures will approach the circle as a limit until the foci coincide, when the ellipse and circle become coincident. The chief point of singularity about the ellipse, then, is that it possesses the peculiar property

of eccentricity, which varies acording to the diversity or coincidence of the foci.

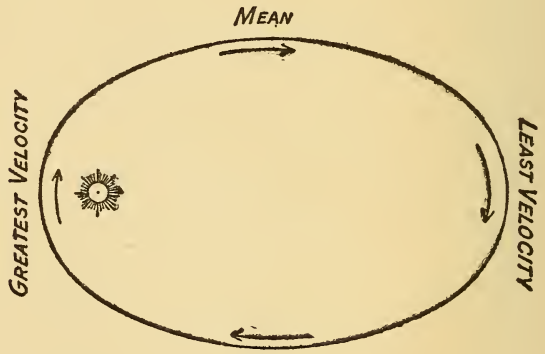
In studying the solar system, we find that the sun, instead of being located in the center of the planetary orbits, occupies the position of one of the foci; which fact enables all the planets to possess one focus in common, lying at the center of their source of heat and light. The first law of planetary motion as discovered and demonstrated by Kepler may be stated in these words:

"Each planet revolves around the sun in an elliptic path, having the sun at one of the foci."

From a conception of this law, we may imagine a sketch of the solar system, with its many planetary orbits varying from approximate circles to greatly elongated ellipses. The orbit of the earth is almost a circle, while that of Venus approaches a circle more nearly still. The path of Mercury is an ellipse which departs very materially from a circle; but still greater eccentricity is to be found in the case of some of the minor planets; while the comets traverse paths of so much eccentricity that the elongated sides appear to be parallel lines.

We say that the heavenly bodies must maintain a certain velocity so that they may complete their journey around the sun in the respective time-periods allotted them. But by this we do not mean to say that these bodies traverse the same identical distance in like periods of time, but, since their velocity is by no means uniform, they move faster at one time than at another. We have previously noted that the earth has to move eighteen miles per second to accomplish her annual journey around the sun; but she does not traverse the

same distance every second of the year, for sometimes she moves more slowly or more swiftly than she does at other times. But her average rate of eighteen miles per second is maintained, so that at the end of the year she is again at the place where she commenced her journey twelve months before.

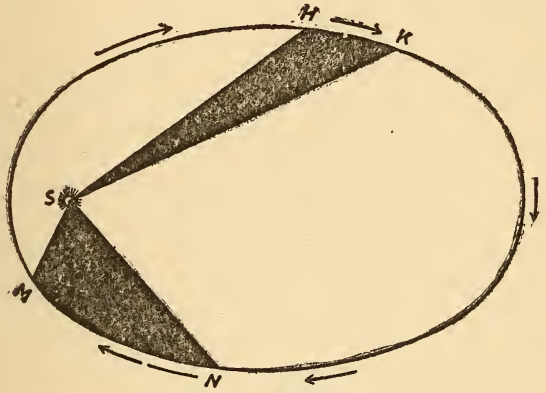


ELLIPTIC MOTION – VARYING DEGREES

We may readily illustrate this important principle to our minds by employing the use of a simple figure. We shall suppose the planet to be situated at that part of its orbit which is most distant from the sun. Here the planet's velocity is at its lowest rate; but, as it begins to approach the sun, impelled thitherward by his wonderful magnetic force, its mean value is attained, and later still, as it passes around the sun at the opposite end of the ellipse, the maximum velocity is reached, which decreases as the planet soars out into space, again attaining its medium rate, to be followed later

by its least velocity, when it reaches the position from whence we first began to observe it.

By an application of Kepler's second law of planetary motion—"Every planet moves round the sun with such a velocity at every point that a straight line drawn from it to the sun passes over equal areas in equal times"—we are able to give numerical definiteness to the principle which causes the velocity of a



KEPLER'S SECOND LAW

planet to vary from the uniform rate. If, in our little figure, the two shaded sections of the ellipse are equal in area, then, according to the second law of Kepler, the planet must take just as long to travel over the arc, H K, as it does to traverse the much greater arc, M N, because, as it departs from the sun, its velocity decreases, and, as it approaches the sun, its velocity increases, which enables it to pass over a much greater arc in the same period of time when near the sun, or

perihelion, than that over which it passes when at the aphelion end of the ellipse. If the areas are not equal, the times required to traverse the intercepted arcs are proportional to the areas.

Thus, the first of these laws defines the path pursued by the planet, while the second gives a description of its varying velocity as it traverses the different parts of its orbit. Since the planets revolve around the sun in elliptical paths, it is but necessary, then, that the planets are nearer to the sun at one time than at another. The average distance, which may be found by taking the sum of the greatest and least of these quantities and dividing it by two, is called the mean distance. By employing Kepler's third law—"The squares of the periodic times are proportional to the cubes of the mean distances"—we are able to make a comparison of the movements of two planets revolving around the same sun.

The "periodic time" of a planet is the number of days which it takes to complete one revolution around the sun. Kepler knew that the different planets have different periodic times, and that the greater the mean distance of any planet from the sun, the longer is its periodic time. The great thinker and philosopher then began to search for the purpose of discovering the relation between these two facts. By knowing the distances of the several planets from the sun, he could readily perceive that it would be incorrect to say that the periodic time of any planet is proportional to the mean distance of that planet. If this were true, a planet having twice the mean distance of another would have double the periodic time of the other; but it was found, by comparing the representative figures,

that the periodic time of the farther planet exceeded twice the periodic time of the nearer; in fact, it was found to be almost three times as great. Kepler, with unwavering perseverance and application, gave himself to the problem, until, at last, after many trials and hardships had been overcome, he found a solution of it, which he enunciated as above set forth.

We may readily illustrate this law to our minds by comparing the relative positions of two planets. It is but a simple matter of calculation to consider the distance of one as unity and of the other as a fractional part, and then square the periodic times of each expressed in days, which shows as a result that the square of the greater number of days is to the square of the less in the same proportion as unity is to the cube of the fraction representing the mean distance of the nearer planet. Considering the mean distance of the earth from the sun as unity, then that of Venus is 0.7233; the periodic time of the earth expressed in days is 365.3 and that of Venus 224.7, from which figures, according to the third of Kepler's laws, the following equation concerning the relationship of the two planets is established: $(365.3)^2 : (224.7)^2 :: 1 : (0.7233)^3$.

Thus Kepler elicited the three great laws of planetary motion, and firmly established them as independent truths; but Newton, by discovering the law of universal gravitation, bound these laws into one indisputable doctrine, and showed that an elliptic path is the only possible course that can be pursued by a heavenly body. No doubt, an object would follow a rectilinear path forever, if it were not deflected therefrom by the force of gravity exerted by some greater body and compelled to swerve in an elliptic orbit. This immut-

able force extends throughout the immensity of space.

The name and fame of these great men, Kepler and Newton, shall remain, ever increasing in dignity and magnanimity as long as time shall last. The glory of Kepler is as immortal as the laws elicited by him; because they, standing as the fundamental doctrine of astronomy, reflect honor and greatness upon the name of him who freed them from the chaos of darkness and night. And, as one expresses it, has not Newton a name among the immortal? How eagerly did he grasp the golden chain, swing from the eternal throne, and, with intense rapture and thrilling delight, climb upward, vibrate through the concave of the skies, gaze upon the stars, and bask in the glorious sunlight of eternal truth that blazed from the center of Deity! "Time's remorseless doom" can never shatter the intellectual pyramid erected by these two master minds.

MERCURY, THE PLANET NEAREST TO THE SUN

Oh, Mercury! thou wing-footed herald of the celestials,
Well dost thou do thy bidding,
And set an ensample for human frailty
To guide us on to higher destiny.

We are often so dazzled by the wonderful genius and the remarkable discoveries of the modern age that we are apt not to be disposed to give the ancients proper credit for the magnificent part which they have had in laying the foundation for the future development of science. Our age is pregnant with so much that is profoundly remarkable, and fraught with so much that is really scientific in its nature, bringing into being new agencies and forces to illumine the pathway of human endeavor, that we are prone to regard the discoveries of the ancient world as commonplace and mediocre. As lightly as we may consider the accomplishments of those philosophers who, during prehistoric times—for their names have not been transmitted to posterity, which is in itself evidence of the fact that they lived and wrought anterior to the dawn of history—gave themselves to the study of nature with their simple, child-like minds untrammeled by foolish sham and flimsy ambition, we shall nevertheless have to accord them a sublime place in the annals of scientific research. Those ancient progenitors of ours, under the serenity of a cloudless sky as they kept watch over their flocks by night, had ample

opportunity to observe the movements of the stars and the changes which took place in the scenery of the heavens.

How gloriously wonderful and singularly beautiful is it to watch the stars at eventime, when they begin "to peep from out the blue" as the angels draw aside the curtain and let them gaze upon us with their silver and golden light! This thought is very beautifully expressed by the poet in figurative form, when he says:

"The angels light their lamps above,
Still mindful of their work of love."

Doubtless it was on one of these glorious evenings in the far-off time that the planet Mercury was discovered. The patient watchers, familiar with the stars, having observed them from childhood, happened to glance across the broad desert plains toward the west where the last rays of the setting sun lingered above the horizon, and there mingling among them they saw a beautiful star, a lustrous gem. Day after day they watched the star, thinking that it would rise higher and higher in the heavens; but in this they were disappointed, for soon it closed in nearer to the sun, where it was lost to view for many months. After a long time the planet came into view again, possibly in the morning as the herald of the day; and, when it had made its reappearance for several times, the astronomers were able, by timing its period of obscurity, to make predictions as to its future return. Thus, probably, was Mercury discovered in a period so far remote that a record of the event has not been preserved.

Mercury may generally be seen during some period

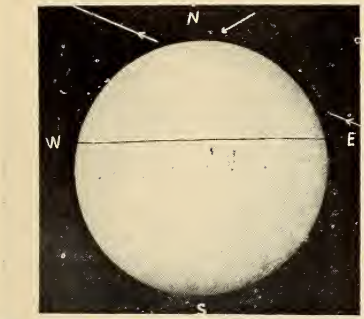
of the year. By consulting the almanac, we may find the period of the year during which he is a morning or evening star, at which time we may get a good view of the shy planet as he wanders a short distance from his sovereign; for, although named for the messenger of the gods, he never ventures far from the protecting care of his chieftain. As near as Mercury is to the sun, it is believed by some astronomers that another planet, or planets, may lie between his orbit and the luminary; but the careful search of these persistent and persevering men of science has not yet been able to discover the supposed planet. Transits of Venus and Mercury across the face of the sun are not rare occurrences; and the astronomers have been observing for over a century to see whether or not they might discover a new planet in the act of crossing the disc of the sun. On several occasions a small sun-spot has been mistaken for the "Planet of Romance." This supposed planet has received the name of Vulcan, who was the god of fire among the Romans, probably from the fact that he is so near to the flaming chariot of the sun that he is obscured entirely by the brilliant rays of that beaming body. But, so far as we are able to determine, Mercury occupies the position nearest to the center of our solar system.

By means of the telescope, Mercury may often be seen in broad daylight, not as a bright shining point, however, as when observed by the unaided vision, but frequently in the beautiful shape of a crescent, resembling a miniature new moon. Mercury is much larger than the moon, but he is so many times farther away from the earth that he dwindles into insignificance. In studying the moon, we spoke of the different phases

of that body which cause her to appear crescent-shaped when new, and then to develop to the full. The phases of Mercury may be accounted for by the same course of reasoning as that to which we resorted in explaining those of the moon. The planet has no inherent light, being, like the moon and the earth, illuminated by the rays of the sun. Since that hemisphere which is turned toward the sun is brilliantly lighted up, we are able to see nothing of the non-illuminated surface and probably only a small part of the lighted surface, which must necessarily have the shape of a crescent. When the planet is at extremes, that is, nearest and farthest from the earth, he presents the appearance of a sphere; but, when he occupies the intermediate positions, he appears to be but partially illuminated, presenting the beautiful crescent effect. When he is nearest to the earth, his bright face is toward the sun, thus rendering him invisible to us, or nearly so.

The planet is so near to the sun that it is impossible to get a clear view of his surface. Attempts have been made to ascertain the character of his surface, and reports have been recorded as to the observation of certain lineal markings across it; but such attempts have been rather futile in establishing any real knowledge as to the configurations of the planet.

In our preliminary survey of the solar system, we made mention of the fact that Mercury completes one revolution around the sun in a period of eighty-eight days, and that his mean distance from the sun is about 36,000,000 miles. The orbit of this planet is an ellipse of so much eccentricity that he sometimes approaches within 29,000,000 miles of the sun and then recedes to a distance of about 43,000,000 miles. According to



1. Transit of Mercury.
2. Venus, Crescent Plan.

(VI., p. 69.)

Kepler's second law of planetary motion, Mercury must sweep with increased velocity over that part of his orbit which is nearest to the sun, and with decreased velocity along that part which is farthest away from the central luminary. His velocity ranges from twenty-three to thirty-five miles per second, according to his distance from the sun, from which a mean or average velocity of twenty-nine miles per second is obtained. This, no doubt, is a terrific rate of speed when compared with that of any terrestrial object, such as a rifle bullet; but, if we take into consideration the volume of the planet, we shall see that, although the bullet passes over the distance of its diameter many thousand times per second, and that the speed of Mercury is at least one hundred times that of the rifle bullet, yet it takes the planet something like two minutes to traverse the distance of his diameter, which fact proves that his speed is not out of proportion to his dimensions.

If we were to divide Mercury's short year of eighty-eight days into twelve periods as we divide the terrestrial year, each month would be just one-third of a day longer than one of our weeks, and a whole season would be only three weeks and one day; while the interval between mid-summer and mid-winter would lack one day of being a month and a half. On account of the eccentricity of the planet's orbit and the brevity of the year, in the short period of six weeks the sun would rise to double his apparent size, while the quantity of light and heat emitted by him would increase accordingly. The terms "aphelion" and "perihelion"

mean respectively "away from the sun" and "near to the sun," and, although we on the earth attach no significance to these expressions, because the slight changes of the earth's distance from the sun are inappreciable insofar as the apparent size of that body is concerned, yet to the inhabitants of Mercury, if he has any—and who can doubt that life in some of its many and varied forms exists there—these terms are fraught with the greatest variety of changes in the vacillating phenomena of his climate.

Mercury is so much nearer to the sun than is the earth that, when he is at aphelion, the intensity of solar radiation is more than quadruple that which the latter body receives; but, when he draws in to the position of perihelion, fully nine times as much heat must be intercepted by him as a result of the sun's radiation as is received by the earth. The temperature there must indeed be scorching. But it is really impossible for us to give any decided account of the climatic conditions of a planet with reference to its position in the solar system, that is, its proximity or remoteness from the source of its heat and light. The density of the atmosphere of any planet will necessarily cause a variation in its climate with reference to heat and cold. From Mercury's position, it is hardly probable that life approximating that of the human species and of the higher brute creation could exist on that planet. As to the habitability of Mercury, it will, doubtless, remain for ages to come enshrouded in the mists of obscurity.

Mercury resembles the moon in one respect, if we accept the discovery made by the distinguished Italian astronomer, Professor Schiaparelli; for, according to

his theory, just as the moon revolves around the earth keeping the same hemisphere turned toward us all the time, so does Mercury make his revolutions around the sun, directing one hemisphere into the light of eternal sunshine and the other into the shades of perpetual darkness. From this we see that the period of axial rotation consists not of a few hours, or the extent of one day, as is the case on the earth, but it extends throughout the entire year. We might expect such a status of affairs as this simply from the fact that Mercury has no satellite to occasion tides on and within himself. But, on account of his proximity to the sun, the solar tides of Mercury must attain an excessive degree of flow and ebb. The tendency of the tides is to compel the planet to present a constant hemisphere to the sun. If in attendance on the planet there were a satellite of such considerable proportions that a great lunar tidal wave swung around that body, then in all probability Mercury would possess an axial rotation altogether different from that which at present exists there.

Mercury is so elusive in his nature, and remains so near the sun, that the astronomers have found some difficulty in determining his mass. However, his weight is estimated to be so much less than that of the earth that it would require twenty-five or thirty globes the size of Mercury to balance the earth.

It may not be out of place here to note the analogy existing between Mercury and the mineral which bears his name. We find that quicksilver has such mobility attaching to it that, when it accidently escapes from the vessel in which we had it confined, it is almost impossible for us to gather it together again, and

especially so since it collects into little globes like shot, which go rolling about in every direction. So Mercury himself, as we have previously stated, is of such an elusive character that we are not able to give him the close study which we are permitted to bestow upon some of the other planets. It would be a priceless treasure to us if we were thoroughly familiar with not only the physical structure of Mercury, but also with that of every planet in our mighty system. But our finite conceptions must remain content with what they possess, until the veil of ignorance is pushed aside and we are able to comprehend the incomprehensible.

VENUS, THE TWIN SISTER OF THE EARTH.

Thou fair-haired angel of the evening,
Now, whilst the sun rests on the mountain, light
Thy brilliant torch of love; thy radiant crown
Put on, and smile upon our evening bed!
Smile on our loves; and, whilst thou drawest round
The curtains of the sky, scatter thy dew
On every flower that closes its sweet eyes
In timely sleep. Let thy west wind sleep on
The lake; speak silence with thy glimmering eyes,
And wash the dusk with silver. Soon, full soon
Dost thou withdraw; then the wolf rages wide,
And then the lion glares through the dun forest.
The fleeces of our flocks are covered with
Thy sacred dew: protect them with thine influence.

Venus, because she is almost as large as the earth, has been called by some the twin sister of our planet. On account of her exceptional brilliancy and beauty, the ancients named her for their goddess of beauty and of love. And, indeed, it was but natural for them to associate this beautiful star with the fabled goddess; for, as she presided over the household of the gods with quiet dignity, shedding her beauty and influence on her celestial companions, so does the star bearing her name emanate to the heavenly spheres around her

luster and splendor, retaining for herself the title that she has ever held, that of being the unrivalled queen of the firmament.

By this we do not mean to say that Venus is the largest star in our system; but simply that she is near enough to us, and also of dimensions sufficiently large, to cause her to appear to us brighter by many times than any other star that glitters in the serene depths of heaven. Indeed she is so brilliant that, when favorably located in the sky, she may be seen in open daylight while the sun still lingers above the horizon to illumine the "listening earth."

Venus, like the other celestial bodies, is very precise in her movements and changes, as may readily be seen by observing the almanac; but to one who does not familiarize himself with this work her actions may seem somewhat capricious. For a long time the famous queen has not been observed; indeed, she has hardly been thought of, when lo! we cast our eyes toward the western horizon where the lingering rays of the sun illuminate the Elysian Fields of the sunset, and there we behold deep-seated on a throne of golden beauty Venus, the queen of evening, bedecked with her jewels. It is a pleasure, indeed, to observe her as she glitters in the sunset glow, and to follow her evening after evening until she reaches the fulness of her splendor. The beauteous transformation which ensues is like that of a glorious human being as his mind expands to comprehend the hitherto incomprehensible, and soars away from the dust of sordid earth to the magic life of divine apprehension.

After Venus has been evening star for a long period of time, she gradually changes her position from the

western to the eastern sky, where she shines as the bright morning star. Here her splendor again rivals the glory of her evening vigil as she climbs the eastern sky the herald of the day. When evening star, she dissipates the gloom of night, making it beautiful instead of terrible and oppressive; and, when she is morning star, her light is but the percursor of that of the golden sun, which is to dawn into the splendor of day. For Venus to go through all these changes requires a period of nineteen months, at the end of which time she commences again to pass the same routine of transformation.

When Venus has reached the zenith of her splendor, she is from forty to sixty times as bright as any other stellar point in the northern skies. Nothwithstanding her exceptional brilliancy, she, like the other planets and satellites, shines by reflected light. Our own planet shines almost as brightly as Venus, the latter being somewhat more illuminated since she is nearer to the sun. Venus, like the moon, because of her position with reference to the earth and the sun, presents a crescent appearance. We are able to see only the part illuminated by the sun, which, to the unaided vision, appears to be a glittering starlike point; but, when it is observed with the telescope, the beautiful shape of the crescent is distinctly discerned. Sometimes the crescent is very thin like that of the new moon, and from this its different aspects vary in shape and form until the planet attains her full.

By observing the position of certain spots on the

surface of Venus, Schiaparelli, the Italian astronomer, demonstrated to the scientific world that this planet, like Mercury, presents the same hemisphere to the sun all the time, thus making the period of her axial rotation equal to that of her revolution around the sun—225 of our days. From this we see that the day of Mercury and Venus is of the same period of duration as their year, which seemingly singular coincidence results from the fact that these planets have no satellites to occasion the occurrence of tides to conflict with the tide-producing power of the sun and thus divide the year into daily periods; and here lies the striking contrast between the planets which have satellites and those which have none. This annual day on the planets which have no satellites would not be compatible with the habits of such creatures as those who form the human species; and yet, in the case of Venus, where indications point to the fact that an atmosphere probably exists and where the spectroscope reveals the presence of water vapor, it might not be beyond credulity to infer that the habitability of that planet approximates that of the earth. Of course, since Venus is nearer to the sun than is the earth, she intercepts more of his heat and light; but there are many modifying agencies which in a measure tend to counteract and modify the intensity and effect of these forces on our globe, and the same may be true with respect to Venus and the other planets as well. And, too, as we approach the equator, where the greatest heat is found, the exuberance and luxuriance of life, both animal and vegetable, are ever increasing, until at the point of excessive heat and moisture life is most abundant. Life like that on the earth would not be

possible, if oxygen were not a constituent element of the planet's atmosphere; therefore, if oxygen be present on Venus, there might be life on that planet not essentially different from some forms found on the earth.

The earth and Venus are almost the same size, the diameter of the latter body being only about 218 miles less than that of the former. When we compare the mass of Venus with that of the sun, we let the figure 1 represent the mass of the planet and 425,000 that of the luminary, which indicates that Venus is only the 1/425,000 part of the weight of the sun. When compared with the earth, the mass of Venus is about three-fourths that of our planet. The specific gravity or density of Venus is about 4.85, which means that Venus weighs 4.85 times as much as a globe of water of equal size; while that of the earth is about 5.58.

In studying the force of gravitation, we found that a body let fall on the earth traverses about sixteen feet in the initial second of its descent; but in the case of Venus the body would fall only about thirteen feet in the first second, on account of the lessened force of gravity.

The orbit of Venus approaches so nearly to the circle that the greatest distance of the planet from the central luminary is not one per cent. more than the least. This indicates that the velocity of the planet does not vary so much as the velocity of those planets which have far more eccentric orbits, its mean rate of speed being about twenty-two miles per second.

The transit of Venus across the disc of the sun is an occurrence more rare than that of Mercury, only two having taken place during the ninteenth century,

while the twentieth century will not have the privilege of recording the event at all. In 1874 and again in 1882 the transit of Venus claimed the attention of astronomers throughout Christendom. Notwithstanding the fact that there are many more wonderful and striking phenomena in the realm of astronomical observation, the two transits of Venus above referred to received such a degree of attention as had never before in the history of the science been accorded to any astronomical phenomenon.

If the transit of a planet is not so beautiful and striking as an eclipse, a shower of meteors, or the appearance of a grand comet, why should it be accorded such a unique place in the annals of astronomy? Of what scientific importance is the transit of a planet across the disc of the sun? In itself it is insignificant; but, when taken as a basis upon which to calculate the stupendous proportions of our solar system, it at once assumes a position of paramount importance. It is the phenomenon which gives to us the scale upon which is constructed the wonderful solar system with its component members—the sun, the planets, the satellites, the meteors, and the comets. All these follow their prescribed paths around the sun, and it is the knowledge conveyed by the transit of Venus which gives us the distance to the sun and enables us to compute the distance of the various planets from one another and from the center of the sysetm. No greater problem has ever engaged the mind of man since first he began to investigate the plenitude of nature.

After securing the scale upon which our system is constructed, which is made possible by the occurrence of the transit, we are then able to determine the

size of the sun and of the planets and the distances of their revolving satellites, and also the number of miles to which the wandering and wavering comets recede and the velocity of the shooting stars. Truly, this is the key to unlock to us the hidden mysteries relative to the size and shape of the solar system.

Since the orbit of Venus around the sun is far less than that of the earth, and since that body moves with a greater velocity than that of our planet, it is but natural that the earth must be frequently passed by Venus as she dashes around the sun. And, since the earth is overtaken by Venus once every year and seven months, it seems that there should be a transit at the occurrence of each of these passages. But this is so far from being the case that frequently over a hundred years must elapse before a recurrence of the phenomenon will ensue. If the earth and Venus lay in exactly the same plane, a transit would occur every time that Venus passed the earth; but, since the path of the planet is inclined to the plane of the earth's orbit, half of the orbit of Venus must be above the plane of the earth's orbit, while the other half must be below; so that, when Venus overtakes the earth, a straight line drawn through the two planets will not usually intersect the sun, but will pass over or under that body. But, should the planets pass each other at either of the points where their orbits intersect, a transit of Venus will occur, because the sun is then in a direct line with the two planets. The transit of a planet is similar in some respects to an eclipse, the material difference being found in the fact that the planet is too small or too far away from the observer to obscure the sun.

It seems somewhat singular that there should be two transits separated by a period of only eight years, and then followed by an interval of over a century before the recurrence of another. In 1761 and again in 1769 a transit of Venus occurred; but it was not until 1874 that the phenomenon was again witnessed, followed at the end of eight years by another. It will not be until 2004 that the next transit will occur; but this will be followed by another in the year 2012. The reason why the transits occur in pairs is to be found in the fact that the periodic time of one planet bears a remarkable relation to that of the other. Venus completes thirteen revolutions around the sun in approximately the same period of time that the earth requires to make eight revolutions, from which fact it is evident that, if the two planets were in line with the sun in 1874, they were again in almost the same position in 1882, and another transit of Venus was the result. We must not infer from this, however, that a transit will occur at the end of each eight-year interval, because it is only approximately true that thirteen revolutions of Venus coincide with eight revolutions of our planet, and the two bodies do not resume the same position with sufficient accuracy for a recurrence of the phenomenon. At the end of the second eight-year interval, then, no transit occurred; for, although Venus passed very near the sun, yet a line drawn through the two planets would have failed to intersect that body.

Although in the history of the race the transit of Venus has occurred hundreds of times, yet the recorded observations of the phenomenon are very few indeed. The great astronomer Kepler foretold that a

transit would occur in 1631, and, although Gassendi diligently gave himself to the study of the phenomenon, yet he nor anyone was able to see it because it occurred at night, which made it invisible to European observers. Eight years later, in 1639, occurred another transit, which was observed by two astronomers, Horrocks and Crabtree.

But it was left to the great astronomer Halley to explain how the distance of the sun can be ascertained by the transit of Venus. This is accomplished by applying the principle of conception known as the parallax. This is readily perceived by placing some object in a vertical position several feet in front of the eyes, and then, by closing one eye and now the other, observing the change which takes place with respect to whatever forms a background. The nearer we approach the object, the more does the apparent displacement increase; and the farther we recede, the less does it become. Thus we see that the displacement varies in the opposite way to the distance, from which we are able to measure the amount of displacement and then calculate the distance from us to the vertical object.

We can apply the principle by using the sun as a background and Venus as the object; for the eyes we place two observatories in distant regions of the globe, and then look at Venus from one observatory and note the amount of displacement which results when we observe her from the other. After measuring the amount of displacement, we can calculate the distance of the planet and also the distance of the sun, which is the scale of the solar system.

Taking all things into consideration, it is doubtful

whether a more interesting body than Venus exists in the solar system. We know very little about her; but it is interesting and instructive to seek for truth with regard to the object of our research; for truth, existing forever, is eternal whether we discover it or not. Without truth, which is eternity's base, no other virtue can possibly exist.

THE EARTH—OUR MOTHER.

Our little systems have their day;
They have their day and cease to be:
They are but broken lights of Thee,
And Thou, O Lord, art more than they.

We owe so much to the earth, and know so much more about her than we do of any other planet, that we may with propriety depart from the strict astronomical consideration of the subject and briefly touch other matters as well. In writing the story of our planet there are many wonderful thoughts, touching her present, past and future, which occur to our mind. We see the wonder and beauty and splendor of her present civilization; we marvel at the glorious achievements of past epochs; and we wonder what of magnificence and grandeur in the way of enlightenment and the discovery of latent truth the future holds in store for us. We must ultimately conclude that mankind, the inhabitants of our planet—for we are ignorant of the existence and actions of beings on other planets—are tending slowly but surely toward the perfection of the ideal; it is the march of progress with matter and ignorance as its beginning and the soul and wisdom as its culmination. The entire transformation is a struggle to pass from ignorance to intelligence, from darkness to light. The story of our little mother and her children is fraught with the most intense interest from the beginning; but it would require volumes to express this story with any degree of fulness, and

so we shall simply note a few of the many things which relate to the earth and to mankind.

Our planet is one of the smaller members of the solar system. She is an oblate spheroid with her polar diameter about 27 miles shorter than her equatorial diameter. The earth's specific gravity is 5.58, or, in other words, she weighs about five and one-half times as much as a globe of water of equal size would weigh. We need not be surprised to find this true, because the earth is composed of substances of weighty material—rocks on the surface and molten iron, greatly compressed by the weight above it, in the interior.

We must understand that the force of gravity exerted by one body may not be the same as that exerted by another. When we weigh an object, we simply measure the force or pull which the earth by the property of gravity exerts over that object. An object weighing one hundred pounds on the earth would weigh only about sixteen or seventeen pounds if transferred to the moon; while, if the same object were taken to the sun, it would weigh about twenty-seven hundred pounds. A man weighing on the earth one hundred and eighty pounds would weigh only thirty pounds on the moon, but the force of gravity would be so great on the sun that he would weigh two and one-half tons. On the moon he might move about with the ease of a beetle, while on the sun it would be impossible for him to sustain himself or even lift his arm. He would spread out into a wafer. On the moon he might run and jump with terrific speed, handle objects of immense proportions, and hurl a ball or rock a half mile or more. This force of gravity varies with the size and density of the globe, being greater on

Venus than on the moon, greater on the earth than on Venus, greater on the larger planets than on the smaller, until we reach the majestic Jupiter and the mighty sun himself.

It is impossible for us to tell the age of the earth. If we accept the nebular theory, the earth, like the other celestial bodies, evolved from some diffused mass, increasing in heat as it condensed until it attained the liquid or semi-solid state, after which it began gradually to cool until a solid crust was formed, and it became a place fit for the habitation of living beings. There are many existing phenomena, such as hot-springs, geysers, and volcanoes, which prove that the earth is still intensely heated; but in the far distant future all this intense heat will have been exhausted and the earth will be, like the moon, cold as the temperature of space.

It has been concluded by the philosophers that heat possesses great astronomical significance. If the moon has lost her heat and is now cold, and the earth and other planets are radiating their heat, must we not arrive at the conclusion that the sun is losing his heat also, especially since he is radiating it in all directions with the utmost prodigality? The law of cooling illustrates to us that every body radiates heat, and the quantity of heat which it radiates increases when the temperature of the body increases. All of the suns and planets are pouring into space a never-ceasing stream of heat, which is productive of very momentous consequences.

Our great luminary emits in all directions an incessant flood of radiant energy in the form of heat, a minute part of which is intercepted by the earth. How

long will the sun be able to continue the emission of heat and thus supply the earth and the other planets? To answer this question, we shall simply indicate the present enormous heat of the sun, from which we shall be able to infer that for ages to come the sun will furnish the encircling worlds with heat and light.

The greatest artificial temperature which we are able to produce is about 4,000 degrees Fahr., and from this we assume the temperature of the sun to be at least 10,000 degrees higher, or about 14,000 degrees Fahr. The outflow of heat from the sun is in proportion to his tremendous temperature. It has been computed that the sun woud in one minute melt a shell of ice 43½ feet surrounding his entire surface. Sir John Herschel estimated that a cylindrical glacier 45 miles in diameter would melt as rapidly as it advanced, even though it were plunged into the sun with the velocity of light. We are told again that from each square foot of the sun's surface emerges a quantity of heat equal to that which might be produced by the daily combustion of sixteen tons of coal. Just a few acres of his surface radiate sufficient heat, if it were properly transformed into work, to propel all the machinery in the world. When we consider the stupendous dimensions of the sun and the vast intensity of his radiation, our imaginations fail to comprehend the vastness of the expenditure of heat.

Since it is from the generosity of the sun that the earth is able to supply sustenance to her teeming millions of beings, we inquire whether the sun may not be exhausting his resources, and, if so, what are the prospects for the future? The thousands of years of history do not record any change in the sun and in

the temperature of those parts of the earth where man has all the while dwelled. There was an age of enormous temperature of the earth which produced the mighty vegetation of the coal period, and in diametrical opposition to that we are reminded of the existence of the age which caused the formation of the glacial sheet; the coal period suggests to us that the earth was hotter then than she is now, and the glacial period that she was colder than at present; from which we cannot reconcile our minds as to the sun's expenditure of heat, but must come to the conclusion that the two periods above mentioned were caused by changes in the earth herself, or by changes in her orbital path. These ages, then, give us very little knowledge relative to the past history of the sun.

The sun, being so much larger than the planets, cools far more slowly; but his heat, if not recruited from some source, must eventually become exhausted. If the sun were a mass of solid coal burning in pure oxygen, the heat produced would suffice for only 6,000 years, a period hardly so long as that of authentic history. If the sun which shone upon the children of the ancient world had been composed of solid coal, he would now be exhausted in consequence of his efforts to maintain his rate of expenditure of heat.

The heat of the sun is in a small degree recruited by the masses of meteoric matter which falls upon his surface. On account of the massive size of the sun, he is able to entrap a multitude of shooting stars, each of which must be attended by a flash of light and heat; and, although it has been supposed that the sun may possibly be re-invigorated from this source, we shall consider the plausibility of the view by esti-

mating the amount of meteoric matter which would be sufficient to maintain the present heat of the sun. It is estimated that, if the moon were crushed into a multitude of fragmentary particles and rained in on the surface of the sun, the shower would supply him with sufficient heat to sustain his present rate of radiation for more than a year. The earth treated in a similar manner would supply this radiant energy for nearly one hundred years; Jupiter would scorch the solar system, or, if properly disbursed, he would suffice to cause the sun to emit his present amount of heat for 30,000 years; while all the planets of our system would be capable of producing sufficient heat, if properly economized, to supply the sun with radiant energy for 45,000 years.

The question for consideration is this: Does a shower of meteors equal in mass to the moon dash into the sun annually? From scientific reasoning we are led to conclude that this is not the case. If space were so filled with meteoric rock that the sun might annually capture a moon-weight of these little bodies, the probability is that so many meteors would dash into the earth and heat her to such an extent as to render her uninhabitable. Again, if such an enormous mass of meteoric matter existed in the vicinity of the sun, the planet Mercury would be affected to such a degree as to cause him to fluctuate in his movements more than is his present wont. Thus we see that the sun must have his radiant energy in the form of heat supplied from some other source or condition.

Scientists have endeavored to solve this momentous problem in a characteristic manner. A great mass of matter widely diffused is supposed to be suspended

in space—and such masses do really exist in the form of planetary nebulae. This globe radiates heat, and, for the purpose of our present supposition, we shall conclude that it emits more heat than it receives from other bodies. Now, although this great mass is imparting its heat, it is incorrect to assume that its temperature is decreasing; for, governed by the law of heat and gases, the temperature must necessarily increase in intensity. The surface layers of the gaseous mass, as they cool, are drawn by the force of gravity toward the center of the globe; and, as the contraction takes place, energy in the form of heat is produced. This heat is in part radiated away, but the contraction produces it more rapidly than radiation can expend it, in consequence of which the globe is losing heat and contracting, although its temperature is actually increasing.*

As the body contracts, it increases in density until it becomes a liquid or a solid, when it no longer obeys the laws of a purely gaseous body, but decreases in temperature until it becomes as cold as space itself. Our sun is now passing from the gaseous stage to that of the solid. If his diameter were to diminish 500 feet annually, which would yield sufficient energy to account for the entire amount of radiation, this would be such a minute part of his enormous volume that he would continue to exist for ages. At this rate, his diameter would decrease about one mile in ten years; therefore, one hundred years ago his diameter must have been about ten miles greater than at present; while one thousand years ago it was hundred miles greater, and ten thousand years ago it was one thousand miles greater. But these figures are but the minutest frac-

tion of the 866,000 miles of his diameter. We gaze into the abyss of the past, and there we see our mighty sun expanding and expanding, with a corresponding decrease in his density, until he becomes twice, ten, or one hundred times as large as he is at present, a mighty nebulous mass filling an immense region of space. The same course of reasoning applies equally well to each of the planets, for, as was set forth in the study of the moon, each of these might have evolved from a nucleal point in this immense mass of gaseous matter. However this may be, for ages to come the sun will dispense light and heat to his planets and satellites, and we shall not suffer for the necessities of life.

*Radium and its marvelous properties, only recently discovered, suggest the probability that the sun's heat may be partly rejuvenated from another source.

The earth, supplemented by the sun's radiant energy, supplies us with the elements essential to life. Water, air, soil, minerals, gases, all elementary forces, may change their form, but they cannot be destroyed, for they are primordial and immortal. In a multitude of ways they minister to our comfort and fulfill the purpose of their Creator. Every natural force and agent exists for a purpose, and it is the province of man to discover an application for each of these primal elements. He has accomplished results little short of the marvelous. His achievements since the dawn of history have been almost enough to stagger credulity, and still there is much more to be accomplished in every line of industry and development, and in every phase of scientific research. It would be absurd to believe, then, that man has discovered an application

for all the forces of nature, or, really, that he is familiar with the forces at all. In the realms of philosophic thought and scientific research, as great and marvelous as his achievements have been, man is yet an infant. We have made wonderful progress in numerous directions during these late [illegible]nd yet the poet sums up our efforts very aptly when he says:

"As we surpass our father's skill,
Our sons will shame our own;
A thousand things are hidden still,
And not a hundred known."

Every potent thought, every good impulse, even, adds to the sum total of the world's achievement; all the efforts of the race to lead men to a knowledge of the true and the beautiful—for, as one says, the object of all knowledge is to enlarge and purify the soul, to fill the mind with noble contemplations, and to furnish a refined pleasure—make the summit of human achievement and earthly glory broader and higher throughout the ceaseless annals of eternity. And all shall not have been accomplished until that state of perfection is attained "toward which the whole creation moves."

Since we are studying the history of our planet, we shall for a few moments deviate from the purely scientific discussion of the subject and lightly touch the story of human achievement and human progress. The history of the race is a record of the development and progress by which it has attained its present state of civilization and enlightenment. This advancement has been made by various stages, as impulses have been brought to bear upon it; and the greatest of these impulsive forces have been conquests, race conflicts, col-

onizations, discoveries, and inventions. The flower and fruit of civilization has grown from the rocky soil of conflict, cultivated by sages and seers throughout long and tedious periods of political and social unrest, and receiving an impetus in its stage of development from the fertilizing thoughts and ideas of all the great and wise men of every age since the time of Solomon and Socrates. Every generation has added its quota to the pyramid of civilization, building it firmer and stronger and higher, until now, with its summit capped with the tranquil peace and prosperity of humanity's harvest, it bids fair to attain a glory and splendor that shall dazzle and illumine the race in its march toward the perfection of the ideal.

Every country, however small and insignificant, has in some way contributed to swell the stream and current of universal history. This wonderful river of human experience is still gaining power, ever propelling us onward toward the millennium of truth. But it is not our purpose to take up the thread of civilization and follow it through the winding corridors of history's labyrinth; we simply wish to note a few significant landmarks along the path of progress.

Civilization has passed through three great periods or stages of development—the potamic, or river stage; the thalassic, or inland sea stage; and the oceanic stage. These three ages have received their names from the bodies of water upon which the race first built its cities and settlements, and, therefore, may be termed respectively the River Epoch, the Sea Epoch, and the Ocean Epoch.

During the River Epoch civilization was confined to the river valleys, like the Nile, the Tigris, and the

Euphrates. Upon the banks of these rivers great cities rose, flourished, decayed, and passed into history, after having borne the torch of civilization and transmitted it to illumine larger areas. This was the inceptive period of the world's history.

The Sea Epoch was that period in the history of the world when the dominant nations grew up around the Mediterranean, and made that sea the arena of man's transcending achievement. Very appropriately, indeed, has the Mediterranean been called the cradle of civilization. On its glassy waters the fleets of those nations carried on maritime trade one with another, and their story is the world's history, they having made this great sea the theatre of their action drama. The age in question was ushered in, during the second millennium before the Christian era, by the Phœnicians, the bold navigators of the time. We owe much to the Phœnicians, because it was they who gathered the seeds of the wisdom of the Orient and disseminated them throughout the nations of the west, where they have blossomed and produced marvelous fruit. Their civilization and culture, their arts and sciences and literatures, are the basis and foundation of ours; and for this reason the Mediterranean nations are looked upon by us as an epoch-making force in the annals of creation.

The Ocean Epoch was opened up by the voyages and discoveries of the fifteenth and sixteenth centuries. During this period the great oceans have ceased to be barriers to human progress, but have become the highway of the nations, by which the world's intercourse and commerce are greatly facilitated. From these facts we observe that man has possessed himself of all the

divisions of the earth—the rivers, the seas, and the oceans—and that the objects of his later conquests must be the currents of air and oceans of atmosphere enveloping the dome of the heavens, and forming for him stupendous highways of trade and travel.

Man is coming to utilize more and more the forces of nature in carrying on his gigantic enterprises; for by individual labor alone the capacity of the human race to produce wealth is not much greater to-day than it was centuries ago, that is the power of unaided human labor has not materially increased. But the world has greatly increased in industries and enterprises as a result of the application of natural forces by the intelligence of man; for, when nature is brought into service, whether it drives an engine propelling a train of cars across the land or a mighty ship across the deep, pumps water, turns a mill-wheel, flashes messages, or what not, it is doing what human muscle would have to do, if the result were to be accomplished at all. The same is true wherever steam, electricity, gravitation, wind, water, or any natural force is used.

Now, is there not the probability that man will discover some even greater force in nature to aid him still further in travel, transportation, and in a multitude of other ways as well? We know that electricity and gravitation, in its astronomical sense, are forces recently discovered, comparatively speaking; we know also that man is annihilating space by various appliances and by introducing ballons and aeroplanes as a means of travel. And here is a thought which almost transforms itself into a prophecy of the golden future of aerial navigation: Why may there not exist in nature certain forces of electricity, gravitation, mag-

netism, etc., wihch may be so related one to the other as to enable man to suspend an airship in space several hundred feet above the earth, and made so to act and react one upon another as to cause the earth to lose her attraction for the ship; and, while the ship itself should be at rest, the earth would turn under it toward the east at the rate of one thousand miles per hour (for the earth rotates on her axis so rapidly as to traverse the 25,000 miles of her circumference in twenty-four hours, the period of her day), so that in a few hours the aviator should find himself leaving the western shores of our continent, entering the broad expanse of the mighty Pacific, traversing Asia and Europe, crossing the stormy Atlantic, and landing on the American continent, having circumnavigated the globe in twenty-four hours? With the atmosphere rushing by him at such a tremendous velocity, it would be impossible as we understand it now for the aviator to exist. Also the gravity of the earth would have to be divided in such a way as not to lose her force or influence over the ship entirely, so that it should not be left in space as the earth sped away at the rate of eighteen miles per second. The idea is to release the earth's attraction to such an extent that she might revolve under the ship but still retain sufficient control over it to keep it in her wake. These and all kindred difficulties would be overcome by years of experiments. Of course, the aviator, wishing to land at any place, would have to be in possession of some power to counteract the existing forces, and then at the psychological moment descend upon the spot desired.

With such forces of nature to aid him, man could accomplish more than ever before. We know not what

the future has in store for mankind; but the history of the past reveals to us that discovery after discovery, invention after invention, has come to aid the otherwise weak and helpless hand of man to perform its tasks; and every one of these inventions and discoveries has in some way been connected with the forces of nature as applied by man's intelligence and ingenuity.

There are many marvelous wonders connected with our earth and the universe. The realms of nature, both in the microscopic and telescopic zones, are fraught with the indefiinable and incomprehensible. The stars in space are wonderful; the beings at our side are more wonderful, because the greatest star is at the eye-piece of the telescope. Of all the wonderful things which God made, man, the wonderer, is himself the most wonderful; therefore, the proper study of mankind is man, for it is he who, by learning the movements of the heavenly bodies, incites our wonder and lifts us still higher in the scale of being. We are told that the mind of Newton, who discovered the law of universal gravitation and showed us how the moon is ever falling toward the earth, is a nobler force and a higher creation than a universe of universes of unthinking matter.

From these observations, we feel more and more inclined to agree with the greatest of all poets in his estimation of man, when he says:

"What a piece of work is man!
How noble in reason; how infinite in faculty!
In form and moving, how express and admirable!
In action, how like an angel; in apprehension, how like a god!
The beauty of the world; the paragon of animals!"

Man's duty is to obey the laws of nature and of God; to make all races fraternal by losing all creeds in the gospel; to follow the paths of usefulness, truth and duty, which alone can lead him back to the great Source from whence he came.

Man may be a creature standing alone in infinity; but the better view is that there are forms of life of every conceivable gradation. As to the habitability of other worlds and the enlightenment and intelligence of their creation, the enshrouded mystery is best set forth by Tennyson:

"This truth within thy mind rehearse,
That in a boundless universe
Is boundless better, boundless worse.

"Think you this mould of hopes and fears
Could have no statelier than his peers
In yonder hundred million spheres?"

MARS, THE RUDDY PLANET.

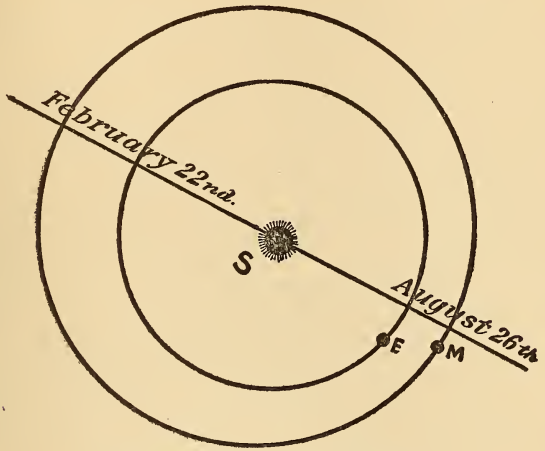
Mars! In thy ruddy color, thou dost resemble
The war-god, from whom thou dost take thy name; but
Let war be no more; upon the earth smile in peace—
Let her rest secure in the light of thy benignant smile.

Next after the earth with respect to distance from the sun comes Mars, the ruddy planet, so called on account of his brilliant red color. With the exception of the moon, we are more familiar with the configurations of the surface of Mars than we are with the markings of any other planet. Mars, unlike Venus, seems to have a rare or thin atmosphere, in consequence of which a closer telescopic examination may be accorded his surface.

The most appropriate time to study any celestial body, located like Mars, is during its period of opposition, that is, when it makes its nearest approach to our planet. When the earth intervenes directly between the globe and the sun, this is called the opposition of the planet. In the case of Mars, his distance is then less than at any other time, and at night he is located high in the heavens, a state of affairs which enables the astronomers to scrutinize him very closely, since the sun is then on the opposite side of the earth.

Those oppositions which occur near the 26th of August are favorable, and those which occur near the 22d of February are unfavorable; for, since the orbit of Mars is more eccentric than that of the earth, at

the former date the distance between the two planets is only a little more than one-half of what it is at the latter. A very favorable opposition occurred in 1877, another in 1909, while the next will occur in 1924, from



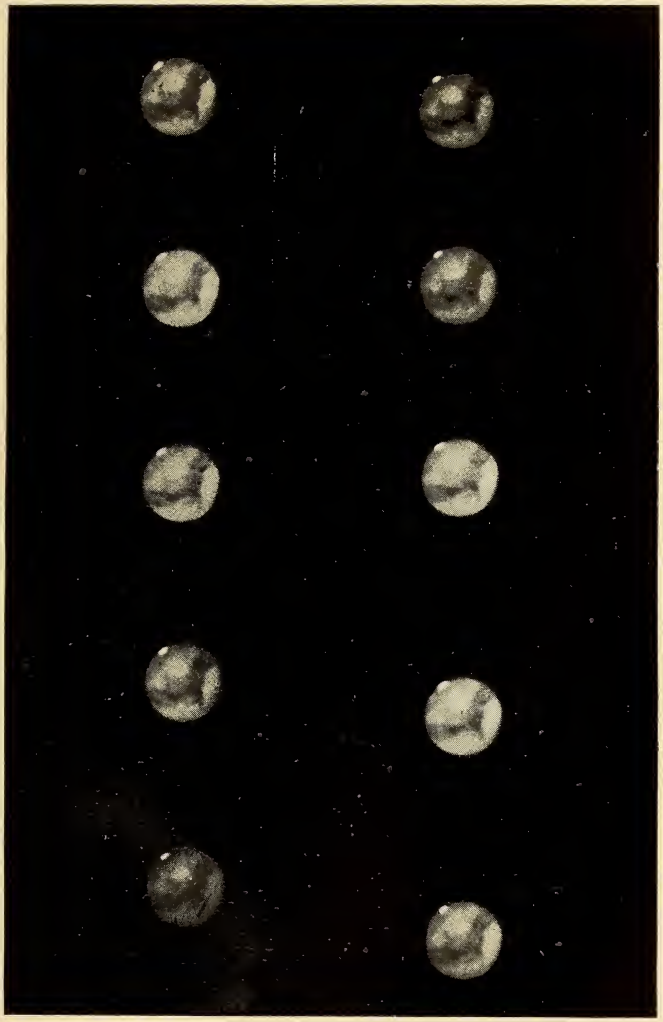
OPPOSITION OF 1877

which we see that they occur at irregular intervals. At a favorable opposition, Mars may approach within 35,500,000 miles of the earth. This close approach of the planet presents a favorable opportunity for obtaining his distance and also that of the sun, thus solving the same problem to which the transit of Venus offered a solution. From the law of gravitation, which causes planetary perturbations, another method of measuring the sun's distance is obtained.

Since Mars requires 687 days to complete one revolution around the sun, his seasons must be almost the

double of ours. He is so much more distant from the sun than is the earth that the heat and light intercepted by him must be far less than that which the earth enjoys. This, of course, has its influence on the inhabitants of the planet, of whom we are entirely ignorant, although the opinion of astronomers is that much higher forms of life in the intellectual scale exist on Mars than exist on the earth. Some have gone so far as to present drawings of the Martians, showing them as large bird-like forms. With each improvement and enlargement of the telescope, we shall learn more and more about our planetary neighbors. If Mars were as near as the moon, we might scrutinize every recess of his surface; but, since he is when nearest almost one hundred and forty times as far as our satellite, we are not able as yet to give him very close study.

The astronomers have divided the variegated surface of Mars into continents and oceans. Professor Schiaparelli, in 1877, discovered a number of long, narrow lines leading across the so-called continents, and to these he gave the name of "canals." There was a network of these canals, which seemed to connect the several oceans with one another. The astronomical world was greatly surprised at this; but, when Schiaparelli announced in 1882 that most of the canals had become double, the astonishment was greater still. During an interval extending from December, 1881, to February, 1882, thirty duplications seem to have occurred, nineteen of which followed, in well-defined parallel lines, canals previously existing. The others were not quite parallel, or were not as perceptibly marked. This singular phenomenon of the duplication



Mars.

(VIII., p. 101.)

of the canals seems to be of a periodic nature, occurring at the time when the planet is passing through his equinoxes. Although we are told that the polar fields, which present the white polar cap, are at the summer season seeking outlets for the melting substance which composes them, yet no explanation of the duplication of the canals has been accepted. For the present, we shall have to remain content without a solution of the enigma, believing, however, that a sufficient explanation will presently be advanced.

We have spoken of the "continents" and "oceans" of Mars, yet it is seriously doubted by some whether water exists on the planet at all. If water in the form of large oceans existed there, then the sun would be reflected from its glassy surface, and we might observe him as a point of brilliant beauty coruscating from the planet.

Mars is similar to the earth in some particulars, although he is much smaller, which causes the intensity of gravitation to be much less there than on our planet. One hundred pounds on the earth would weigh rather less than fifty pounds on Mars. But the period of his axial rotation is but little more than half an hour greater than that of the earth, being 24 hours, 37 minutes, 22¾ seconds. Since he rotates on his axis in a period of time less than his year, we may feel sure that he must possess a satellite. Mercury and Venus, having no satellite to produce tides and cause diurnal rotations, present the same face to the sun all the time, and thus the length of their year and day are

identical. But this is not the case with Mars; therefore, he must have an attendant. For years the astronomers sought diligently to discover the Martian satellite, but all to no purpose. Finally, Professor Asaph Hall, furnished with a telescope of colossal proportions and exquisite workmanship, decided to make another effort to discover an attendant to Mars. Professor Hall knew that, were the satellite the one-hundredth part of the moon, it would have been discovered long before this time; therefore, he prepared for a very diligent search. Victory doubly crowned his efforts, for he discovered two satellites, one of which, Deimos, revolves around the planet in 30 hours, 17 minutes, 54 seconds; while the other, Phobos, completes one revolution in the exceedingly brief period of 7 hours, 39 minutes, 14 seconds. Deimos completes a revolution in about one and a quarter days; but Phobos revolves around the planet three times while he is making one axial rotation, which fact is unparalleled in the solar system, and probably in the universe. Our earth rotates twenty-seven times while the moon makes one revolution; while Jupiter and Saturn rotate several times on their axes while their satellites are completing one revolution. The sun himself rotates several times while even the nearest planet, Mercury, is completing the circuit of his orbit. No other known case exists where the satellite revolves in less time than the primary rotates. Another singular occurrence with respect to this inner satellite is the fact that he moves around his primary in an opposite direction to the habit of celestial bodies, rising in the west and setting in the east.

When Professor Hall had made his remarkable dis-

covery, he consulted his literary friends as to the names which the satellites should bear. The Iliad of the great Greek poet, Homer, suggested the names for the newly discovered Martian moons. In ancient mythology Deimos and Phobos were the attendants of the god of war; and in this later day, when the satellites of Mars were discovered, they were given the same names that characterized his attendants in the far off time of the mythological past. Our moon is nearly a quarter of a million miles from the earth; but the satellites of Mars are close to their primary, Phobos being less than 4,000, and Deimos less than 13,000 miles above the surface of the planet. These are very small bodies, with diameters of twenty-five or thirty miles. But there are many more small globes in the great solar system; not necessarily satellites, however, but minor planets.

There is a wide area of celestial territory lying between the orbit of Mars and that of Jupiter. For a long time it was thought that this space was occupied by some planet, the discovery of which had not yet been made. After the enunciation of Bode's law, which shows that the planets are relatively located according to a certain series, more attention was directed to the search of some tenant for the occupancy of this great space. In the series 0, 3, 6, 12, 24, 48, 96, each number except the second is the double of the number preceding. If now we add four to each, we have the series 4, 7, 10, 16, 28, 52, 100, by which the planetary members of our solar system are approximately stationed with reference to their distance from the center, or the sun. The real distances are: Mercury, 3.9; Venus, 7.2; Earth, 10; Mars, 15.2; Jupiter, 52.9; Saturn, 95.4. But as yet no known planet occupied the orbital position

represented by 28, the fifth number in the series; and so, about the close of the eighteenth century, the astronomers began to search more diligently for the surmised little planet.

In the first week of the wonderful nineteenth century the astronomer Piazzi discovered the first of the minor planets, and a little later the celebrated German mathematician, Gauss, began his memorable career by tracing the planet's orbit through the heavens. Piazzi observed the little planet, afterwards called Ceres, on several consecutive nights and indicated her position, from which, having as many as three positions clearly defined, the mathematician was able to compute her orbit and point out where she would be at any time in the future. Although the season soon passed and she could be seen no longer in those parts of the heavens, yet Gauss told the astronomers where they might observe her at a given time gliding among the stars; and, when they turned their telescopes to that part of the sky indicated by the mathematician, there was the little planet wandering through a different constellation. Since that time Ceres has been followed so closely by mathematical accuracy that her place in the system for every night in the year, whether she may be seen or not, may be correctly indicated.

The discovery of Ceres was within a few years followed by that of Pallas, Juno and Vesta. The orbits of these little bodies lie between those of Mars and Jupiter, thus utilizing the vast area between these two major members of the solar system. Many more have from time to time been added to the list of minor planets until now they number between six and seven hundred.

In the search for new planets, a certain section of

the heavens was observed for several nights together and the position of the stars indicated; after this their places on the several nights were compared, and, if the position of any one varied, it was a planet, or wanderer. But a more significant method is now used. A photographic plate is exposed to a certain section of the heavens, and upon this the stars imprint their images. To the camera is adjusted some very delicate machinery, by which the instrument is made to keep accurate pace with the rotation of the earth, so that every fixed star may imprint its image as a sharp, well-defined point on the photographic plate. The planets, however, if any happened to be traversing that part of the sky when the exposure was made, indicate the fact by a streak on the plate, which manifests itself on developing the film.

For aught we know, the physical structure and composition of the asteroids may be the same as that of the earth or of the other planets. They may be miniature worlds, with their surface subdivided as that of the earth. But even though everything necessary to human existence were to be found on these little worlds, still they would not be fit abodes for such beings as we are. The force of gravitation would be reduced to such a degree that highly organized beings would find it impossible to reside on these minor globes.

Although Ceres and some of the others first discovered are larger, yet we may readily illustrate this fact by employing a globe one hundred miles in diameter, which would be one-eightieth of the diameter of the earth. If the materials of the asteroid were of the same nature as those of our planet, the force of gravity on the surface of the miniature globe would be only

one-eightieth of what it is on the earth. One ton on the earth would weigh only twenty-five pounds if transferred to the asteroid. A man there could lift eight tons with the same exertion that he uses to handle two hundred pounds on the earth. This difference in gravity would occasion a stupendous change. But suppose that we try the experiment on a globe just eight miles in diameter, which is only the one-thousandth part of that of our planet. The force of gravity would be only the one-thousandth part of the terrestrial force. An object weighing one thousand pounds on the earth would weigh only a pound if transferred to the little globe. A man could lift one hundred tons on the asteroid with the same exertion that he puts forth to raise two hundred pounds on the earth.

As we have previously intimated in several instances, it would be utterly impossible for life, such as we know it, to exist on the satellites and minor planets on account of the absence of an atmosphere. It is the action of the air, the wind and the rain, the frost and the snow, which causes the elevated portions of our earth to be constantly worn down, with the sea-level as a limit; but, since the moon has no atmosphere, we may observe her mountains for countless ages without the detection of any change, because there none of these elements is at work, and the entire body is as silent as the tomb. The crags and mountain peaks are sharply defined, attaining a ruggedness seldom found on the earth. And, although we cannot see the ruggedness and sharpness of land forms, if land exists, on the minor planets, yet we believe that no atmosphere is present there and that they are as silent and lifeless as our satellite.

To give an explanation of the absence of an atmosphere from the satellites and minor planets, we must consider the molecular velocities of certain gases with which we are familiar on the earth. Modern research has discovered that a gas is composed of an immense number of molecules, each of which is in exceedingly rapid motion. But this motion is pursued for only a short distance in one direction before the molecule comes into collision with another molecule, which fact within itself causes the directions and velocities of the individual molecules to be ever and continuously changing. Each gas has a certain average molecular velocity which is common to the molecules of that gas at a given temperature, and, when several gases are mixed, as nitrogen and oxygen are in our atmosphere, the molecules of each continue to preserve their characteristic velocities. It is estimated that near the earth's surface the average velocity of nitrogen and oxygen molecules is about a quarter of a mile per second; while that of hydrogen molecules is a mile or more per second, being the greatest molecular velocity of any known gas.

From our knowledge of the law of universal gravitation, we have become familiar with the fact that the greater the mass of any body the more gravitational force does that body possess, and the "critical velocity" or initial speed of any projectile hurled from a large globe never to return must be greater than that of a small one. The initial velocity of the earth is about seven miles per second; that of Mercury three miles per second, of Mars three and a half, of Saturn twenty-two, and of Jupiter thirty-seven; while that of the sun is so great that, if a projectile be hurled from his sur-

face never to return, it must leave the great globe with an initial speed of 391 miles per second. And thus we explain why free hydrogen exists on the sun and why it does not exist on the earth. The velocity of this gas at the earth's surface, we have said, is about a mile per second; but by a combination of circumstances it might happen that the molecules of this gas would soar above the earth and not infrequently attain a velocity of seven miles per second, which would project them away never to return. But the gravitational force of the sun is so great and requires such a high initial velocity, that even the hydrogen molecules with all of their speed can never attain it and can never escape. The molecular velocities of the other gases on the earth are so low that they cannot possibly escape; and thus are found nitrogen, oxygen, water vapor, and carbon dioxide forming component parts of our atmosphere.

This course of reasoning applied to the moon and minor planets will reveal to us why no gases remain on them to form an atmosphere. The critical velocity of the moon is about a mile and a half per second, which is within the maximum velocities attainable by the molecules of nitrogen, oxygen, and other terrestrial gases. Thus these gases, if they ever existed on the moon, have in the course of time escaped and left her without the possibility of life as we know it on the earth. Since the minor planets are far inferior to the moon, their gravitational force is so slight as to allow the escape of those gases which might contribute to the formation of an atmosphere. On an asteroid of only a few miles diameter even a child might toss a ball with sufficient velocity for it never to return. The

critical velocity of any planet is proportional to its diameter; therefore, the critical velocity of an asteroid eight miles in diameter, which is about the thousandth part of the earth's diameter, would be the thousandth part of seven miles per second—a little over thirty feet. From this it is readily perceived that small bodies are not capable of retaining gases which might serve as an atmosphere or blanket to shield them from outside disturbances or influences.

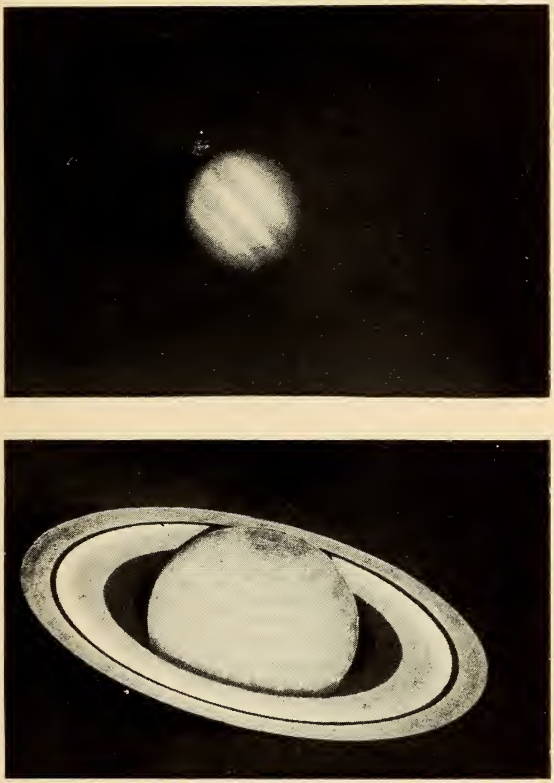
A world of philosophy lies in each of these small bodies; and, although our greatest attention is given the larger globes of the solar system, yet these infant worlds are as truly the product of the Creator's handiwork as the mightiest globe in the universe of God. Even small things command our attention and direct us to the Giver of all life and the Source of all power.

JUPITER, THE GIANT PLANET OF THE SOLAR SYSTEM.

These are Thine orbs of light and shade;
Thou madest Life in man and brute;
Thou madest Death, and lo Thy foot
Is on the skull which Thou hast made.

In a survey of the solar system, if we were to proceed according to the size of its members, we should, of course, find Jupiter coming next after the sun himself, since he is the largest planet in attendance upon our great luminary. The ancients called their chief deity Jupiter, and it so happened that they also conferred upon the greatest of the planets the name of their most powerful and most important god. Jupiter may be considered the planetary king of the solar system. He is of such majestic proportions that, if Saturn, the next largest planet, were augmented by all the other members of the solar system, the mass of this great globe would not equal that of Jupiter. Truly he is a wonderful globe, fitted by his supreme command to hold sway over the lesser lights of our system.

Beginning with Jupiter, a great descent in the scale of magnitude must be made before Saturn is reached, and another downward step must be taken before



1. Jupiter.
2. Saturn.

(Ill., p. 110.)

Uranus and Neptune are approached; while the lesser planets, to which group our earth belongs, are so small that they may be considered as the infants of the great sun-family.

Jupiter's mean distance from the sun is about 483,000,000 miles, or a little more than five times the earth's distance from the luminary. The ellipticity of his orbit is very appreciable. Jupiter, like the other planets more distant, illustrates the law that the farther a planet is from the sun the slower is its orbital velocity. The earth, as we have before seen, passes over eighteen miles per second as she journeys around the sun on her orbit, while Jupiter traverses only about eight miles per second. The outer planet has a longer journey to accomplish than has the earth, and he covers this at a much reduced rate of speed; therefore, for this two-fold reason, a longer journey and slower velocity, Jupiter requires nearly twelve of our years to complete one orbital revolution around his primary.

The mean diameter of Jupiter is nearly 87,000 miles. A very conspicuous difference exists between his equatorial and polar diameters, caused by the rapidity of his axial rotation; for, although Jupiter is about 1,300 times the size of the earth, he rotates on his axis in less than half of the earth's period of rotation, in fact, completing one rotation in 9 hours and 55 minutes. The rapidity of this rotation causes him to bulge at the equator, which makes the equatorial diameter considerably greater than the polar. A clear conception of this swift axial rotation may be obtained by comparing the velocity of a body on Jupiter's equator with the velocity of a body situated at the equator of the earth. A body at the earth's equator moves a little

more than a thousand miles per hour, while on Jupiter the body would travel almost twenty-seven times as fast, which fact accounts for the marked ellipticity of the giant planet; for the rapid rotation develops a great centrifugal force which bulges out his pliant form.

From measurement we are informed that it would take 1,300 globes the size of our earth to equal the volume of Jupiter; but from the laws of universal gravitation, which reveal the mass of a celestial body, is deduced the fact that Jupiter weighs only 316 times as much as the earth. As a result of this reasoning, it must be concluded that the materials of which Jupiter is composed are less compact than those forming the earth. In fact, it seems that he must be in a state of "diffused expansibility," through which the earth passed countless ages ago. He is composed of nebulous matter not yet condensed into as compact a body as the earth and some of the other planets. Clouds always shield the surface of Jupiter from a close telescopic scrutiny, so that he cannot be accurately viewed by the astronomers; but, notwithstanding this, the ever-variable belts which appear on the giant planet are objects of beauty and interest. These are caused by the light of the sun, and suggest to us an idea of how the heat-belts of the earth might appear if we could observe them from the proper distance.

Jupiter is attended by a beautiful retinue of satellites, and it is to them that we owe our knowledge of Jupiter's weight; for from the observation of his moons we are able to measure his attractive power, and calculate as a result the mass of the mighty planet. Again, when a minor planet approaches near his orbit, it is attracted by the mass of Jupiter and made to swerve

from its path, from which the amount of deviation can be measured and Jupiter's mass calculated. Comets may dash into the solar system and approach Jupiter, who will cause them to deviate widely from their paths; and, just as the perturbation of the planets gives us the opportunity of measuring Jupiter's mass, so do the deviations and disturbances of the comets present us with data for the same purpose. The results obtained from the satellites, planets, and comets are approximately identical, from the coincidence of which we are assured as to the weight of Jupiter's mass.

As large as Jupiter is when compared with the other planets, he dwindles into insignificance when contrasted with the mighty mass of the sun. About 1,047 Jupiters, all rolled into one great globe, would equal in weight the luminary of our system. Jupiter occupies a position with respect to heat and density intermediate between the sun and the earth. We account for the disparity between the size and mass of Jupiter and the same attributes of our earth by taking a retrospective glance at the condition of the earth in the remote ages of the past. Then the earth was hot and glowing, and her materials widely diffused—a condition analogous to the present one of Jupiter; but as she cooled her materials contracted and became more and more compact until she evolved into a place fit for the habitation of highly organized beings. Her materials, widely diffused, occupied more space then than now, thus giving her larger size; but the weight of these materials with their high temperature was the same as it is at present. The water and possibly some of her other substances were transformed into vapor, and the atmosphere was charged with tremendous

clouds, thus greatly augmenting the size of our planet. Viewed from a distant point in space, the cloud-laden atmosphere would indicate the visible size of the earth, while her average density would accordingly appear to be far less than it is at present. Although Jupiter may not now be a fit habitation for life such as we know it, yet in the distant future he may be the home of teeming millions of beings blessed with all that can please and prosper the possessors of life. Considering his enormous size, though the cooling process will probably reduce it to a certain extent, what glorious nations might exercise sway over his broad expanses of surface, and what races of beings might evolve from the dust of his plains! Since he is so far from the sun, it would hardly seem probable that human life could exist there; but conditions in the wisdom of an overruling Providence may not be a barrier or a limit to life in some of its numberless forms.

At present it would seem that great storms and tempests, cyclones and hurricanes, ever disturb the surface of Jupiter. These may be far more violent than the storms with which we are familiar on the earth. The solar heat intercepted by Jupiter must be small indeed—hardly the twenty-fifth part of that received by the earth in proportion to surface; but the great internal original heat of the planet may be the engendering cause of the violent disturbances which convulse the mighty globe. The sun himself is distracted by violent tempests as a result of his intense internal fervor.

Jupiter and his satellites present a very striking and pleasing picture when they are observed through merely a common telescope. The little moons at first

glance resemble stars; but soon it is observed that they are not stars, for they follow the great planet in his ceaseless wanderings through his entire circuit of the heavens. As he swings in his majestic orbit, the little attendants encircle him each with a different period of revolution. It must be singularly beautiful to see several moons in the sky at the same time, one following behind another with its allotted velocity and its proper distance from the planet. Since the nearer satellites have a shorter journey to pursue, they overtake the outer moons and pass them in the sky, which action is doubtless very beautiful to behold. It would be wonderful to see several moons gliding by one another in their journeying about the planet.

Viewed from the earth, the eclipses and occultations of Jupiter's satellites are very striking phenomena. The transit of a satellite across the disc of the planet is beautiful, not so much from the passage of the moon since it may be scarcely seen on account of the brilliancy of the planet, but on account of the dark shadow which it casts upon Jupiter's face. Some of these satellites are larger than our moon, but, on account of their great distance, it is difficult to perceive any markings on their surfaces, although it is believed that they, like our satellite, always turn the same face to their primary.

We speak frequently of the marvelous velocity of light, and say that it travels at the rate of 186,000 miles per second. Even at this tremendous rate, it takes a considerable interval to reach us from the sun and distant planets. It was formerly believed that the passage of light over any distance was instantaneous, but, from an observation of the eclipses of Jupiter's

satellites, it has been determined that light travels at the enormous rate of speed above mentioned—186,000 miles per second. How do the eclipses of Jupiter's moons aid us in calculating the velocity of light?

These eclipses had been observed for many years, and it was found that certain order reigned among them just as we perceive throughout the phenomena of the entire universe. From these observations the astronomers predicted the recurrence of the eclipses, but their calculations would vary from the exact time of the occurrence, the eclipses taking place five or ten minutes before the computed time or five or ten minutes after it. At first the astronomers were bewildered to know what caused the error in their calculations; but really there was no error, but the difference in time of the eclipses resulted from the fact that at one period Jupiter was nearer the earth than at another; and during the period of his opposition the eclipses would occur a few minutes before the predicted time, and when he was farthest from the earth they would occur after the predicted time. This remarkable fact led the Danish astronomer, Roemer, to the conclusion that light requires time to make its passage over any given distance. As the satellite entered the planet's shadow, the last rays of light were those which gave the astronomers knowledge of the occurrence by entering the telescope and impressing the picture upon their minds. It requires some time for the long stream of light which left the satellite when it entered the planet's shadow to reach the astronomer, which fact led to the discovery of the velocity of light. Thus, when the earth was comparatively near to Jupiter, the light had a shorter distance to travel, and the eclipse

would occur sooner by a few minutes than the time predicted; but, when the planets were at their greatest distance apart, it would occur later than predicted. From these facts the velocity of light was computed and the variableness in the eclipses explained.

The velocity of light has also been computed from the use of a very delicate instrument which flashes the light of a lantern through a narrow slit to some reflector in the distance, while a wheel with spokes is so arranged as to turn the spokes and intercept the rays; from which, knowing the rate at which the wheel is turning, the velocity of light is calculated. The result obtained by mechanical means is approximately the same as that which the eclipses of Jupiter's satellites afford. It is very interesting to note the noble uses to which discrepancies may often be put. The failure of the eclipse to occur at the time predicted led to the discovery of the velocity of light, which is a great addition to the quota of astronomical science.

Jupiter and his satellites illustrate to us on a miniature scale the conception of the solar system. Typical of the sun, he is the center of the system, while his moons are identical with the planets which ceaselessly swing around their primary. It was formerly believed that the earth was the center of space and that all the celestial bodies revolved around her as the "hub" of the universe; but, when the newly invented telescope was turned upon Jupiter and his moons, this narrow idea was cast aside and the Copernican theory of the universe given full recognition everywhere. Some so-called philosophers believed that Aristotle, the eminent Greek scholar, had sketched properly every topic pertaining to the material universe; and some of

them went so far as to deny the existence of satellites in attendance upon the planets. One of these men refused to look through the telescope, when invited to do so by Galileo, for fear that he should see and be compelled to believe; but, when he died, which occurred within a short time, Galileo said: "I hope that he will see the moons while on his way to heaven." And, following the thought of Galileo, we are impressed with the great fact that in the spirit land we shall survey the universe and comprehend the glory of the heavens.

Saturn.

SATURN, THE PLANET WITH THE RINGS.

Lord of life, beneath the dome
Of the universe, Thy home,
Gather us, who seek Thy face,
To the fold of Thine embrace,
For Thou art nigh.

Saturn formed the boundary of the solar system so far as the knowledge of the ancient world was able to judge, for he formed the fifth and last planet in the estimation of primitive astronomers. He is the second planet in size in the solor system, and is a marvel of beauty and interest on account of the wonderful system of rings which surround him. To the unaided vision he appears to be about as brilliant as a star of the first magnitude. He might have been mistaken for a star, were it not for the fact that he changes his position with reference to the other heavenly bodies, which caused him to be placed in the category of orbs which have no fixed abode in the skies, but wander about the circuit of the heavens.

Saturn is stationed at a profound distance in space, being on the average about 886,000,000 miles from the sun; it takes him twenty-nine and one-half of our years to complete the stupendous journey around that body. Being still more distant from the sun than Jupiter, he moves more slowly along his orbit, his average rate

being nearly six miles per second. His orbit is a very appreciable ellipse, on account of which, from one of Kepler's laws concerning the theory of gravitation, he varies in his velocity as he swings around the sun.

Saturn is a very large planet, having a mean diameter of 71,000 miles. His ellipticity, like that of Jupiter, is very marked as a result of his high rate of axial rotation, for he completes an entire rotation in 10 hours and 14 minutes. His density or specific gravity is less than that of any of the other planets, being even less than water itself, upon the bosom of which, if an ocean large enough to sustain the planet existed, he would float with one-fourth of his mass above the surface. From these facts it would seem that Saturn is in even more of a nebulous state than Jupiter, and that he has retained more of his original heat; but from the law of cooling is evolved the truth that the smaller the body the more rapidly does it cool and impart its heat. In the case under review, modern science has not been able to reconcile the discrepancy, and so the problem must remain unsolved for the time being. Yet, notwithstanding the porosity of Saturn, he weighs more than ninety-five times as much as the globe upon which we dwell, and 3,500 globes each as large as Saturn would weigh as much as the sun.

With the unaided vision it is impossible for a terrestrial observer to see the beautiful system of rings by which Saturn is surrounded. When Galileo with his newly invented telescope, which was of low magnifying power, began to scrutinize the heavens, he was impressed with the singular beauty of the spots on the

sun, the mountains on the moon, the crescent of Venus, the satellites of Jupiter, and the many other interesting bodies which bedeck the sky; but, when he centered his attention upon Saturn, he was amazed at the appearance which the planet presented. At this time there appeared to be three bodies near together touching one another, with the largest between the other two. Galileo was naturally puzzled at this, and knew not how to explain it; but, when, after observing the interesting bodies for a time, the two appendages disappeared and left by itself the globular disc, he was more confounded still. He thought probably that the phenomenon was a delusion and that Saturn after all was simply like the other planets. But in the course of time the appendages, which Galileo had described as globes, began to reappear, and then it was that their true nature was discolsed.

Nearly a half century later Huyghens proposed a solution for the problem, and showed that instead of being globes they were crescents with the concave side turned toward the planet, and that, when they disappeared, they were but turned edgewise to the earth, which prevented the astronomers from seeing them at all. Soon they began to reappear, and gained their largest proportions, apparently speaking, during an interval of seven or eight years, at the end of which time they were again edgewise to the earth. It takes them about fifteen years, or half of Saturn's period of revolution, to go through the changing cycles of their movement. When Saturn is in the proper position for his appendages to be seen best, they produce a beautiful ring surrounding the planet, and not the globular appearance which they presented at the time when they

were first seen by Galileo. Huyghens demonstrated that the ring rotates around the globe.

Modern research has shown that a dark line, supposed to be an aperture, separates the ring into sections, or rather into independent rings. The inner of these is again subdivided by a faint line, and the ring nearest the planet is so thin and fragile as to be called the "crape" ring. A faint line marks the outer ring also, from which we see that there are apparently four divisions of the ring-like structure. The astronomers have not, as yet, been able to show exactly how the rings rotate, whether in sections or in one solid division.

The law of gravitation, pervading every part of the universe, is the source to which we look for an explanation of many otherwise inexplicable phenomena which are presented to us in the study of astronomy. The prevalence of this great law is demonstrated by Saturn, as it is by every body in the universe, as he guides and controls the beautiful system of satellites by which he is encircled. His system of rings are under the same influence and are held in their proper place by the gravitational force of the great planet. If these rings were composed of the stoutest steel, they would be crushed to the surface of the planet; for, if we imagine ourselves standing on Saturn, the rings would form a magnificant arch with a span of upwards of one hundred thousand miles stretching above us and down to the horizon on either side; and this would be far too long, considering the attractive force of so large a planet, to sustain itself for even a moment, regardless of the strength of the materials forming it.

The idea of solid rings must at once be pushed aside for something more feasible. If we suppose that the rings were made of water vapor, as are the clouds on the earth, which, though composed of millions of little drops so closely placed as to present a continuous appearance at a short distance, float above the surface, nevertheless this theory must be abandoned for a more plausible one, because a wave-like motion would develop and destroy the equilibrium of their movement and lead to a disruption of the rings themselves.

Probably the only possible way for us to reconcile this singular phenomenon to our minds is to assume that the rings are composed of a multitude of little bodies like the sands of the sea, floating in a shoal around the great globe, each following its own well defined orbit, the whole comprising and presenting a continuous stratum encircling the planet. This beautiful shoal swings around the mighty globe, each little member following its allotted path with the utmost precision, guided ever by the influence of the powerful planet in the center. Since all of these minute bodies are assumed to be satellites, it is possible for us to compute the time required for them to revolve around the planet. A satellite at the outer edge of the ring would require about 13¾ hours to complete the journey; and one near the middle would complete the circuit in about 10½ hours, while a satellite situated at the inner edge of the ring would accomplish its rotation in about 7½ hours.

On a much grander scale we find in the solar system an analogous case to the curious phenomenon presented by Saturn and his encircling rings. The sun is surrounded by a vast array of minor planets; and, if

these were greatly increased in number and their orbits all drawn into one plane, they would then present a ring-like appearance not wholly unlike that swinging around Saturn. This mighty planet with his rings and satellites presents a favorable impression as to the structure of the solar system itself; for the rings may be assumed to represent the vast shoal of minor planets, and the satellites to represent the larger planets in their revolution around the central body. However beautiful and fascinating this theory may be, we trust that future observation will reveal the true nature and character of the Saturnian system, and show whether or not the rings are of a permanent existence like that which attaches to the planets and satellites.

In 1655, Huyghens, who discovered the true form of Saturn's rings, was examining the planet, when he perceived a small star-like object in attendance upon the great globe. This was the first discovered satellite of the Saturnian system. Huyghens abandoned the further search for satellites, because he was in some way led to believe that the number of secondary planets (satellites) should be the same as that of the primary planets. Including the earth, there were six planets, and there were now after Huyghen's discovery six satellites—one in attendance upon the earth, four revolving about Jupiter, and one following Saturn in his wanderings through the heavens. Thus the system was complete in the estimation of the astronomers of the time. But afterwards it was discovered that many more satellites owed allegiance to Saturn, and this caused the collapse of the theory upon which Huyghens relied, for it demonstrated the doctrine of

numerical equality between planets and satellites to be grossly absurd. So the number of satellites soon superseded that of the planets; but this did not hold true indefinitely, for, since the discovery of so many minor planets, the number of primaries is now greatly in excess of the number of secondaries.

After a few years, the astronomer Cassini discovered four other satellites swinging about the great planet, and following him as he coursed his way through the boundless skies. The Saturnian system was now more complex than that of Jupiter, for up to this time only four of Jupiter's moons had been discovered, while Saturn was known to possess five. But toward the end of the following century (eighteenth), Herschel, having improved and enlarged the vision of the telescope, discovered still another satellite attending Saturn. At the moment when it was first seen, Herschel was unable to distinguish it from a fixed star, but later observation informed him that the tiny point of light seen by him was really a little moon, for it followed Saturn through the heavens as he sped on his great orbit around the sun. Herschel, with that thoroughness and ingenuity which characterized his every effort, in a short time discovered another tiny satellite situated so close to Saturn that it is obscured by the radiance of the rings for much of the time, and may be seen only during the brief intervals when it emerges from the wardship of these curious appendages.

It was nearly a half century (1848) after the discovery of this seventh satellite when still another was discovered and added to the Saturnian system; but even this did not complete the number of Saturn's

children, for after the elapse of fifty years (1898) the ninth satellite was observed, while still another was added in the first half decade of the present century.

Considering the number of Saturn's moons and the singular phenomena presented by his beautiful system of rings, he must be regarded as one of the most complex and intricate, and also interesting, bodies known to the astronomer. One is inspired with awe and reverence as he looks upon the grandeur of this mighty orb—a globe fit to be the boundary of the majestic solar system to which, in the infinity of worlds, we are assigned. Little did our progenitors of a few centuries ago dream that beyond this splendid planet, which they might have considered as the guardian of our system, lay two other majestic orbs, reflecting the beauty of the sun and guided ever by his wonderful and potent influence.

The discovery of these two planets, Uranus and Neptune, marks one of the most momentous epochs in the whole history of astronomy, while the discovery of Neptune may be regarded as the greatest purely intellectual feat in the annals of human achievement. Such acquisitions to the pyramid of science cause it to lift its radiant summit toward the heavens and bask in the glorious sunlight of eternal truth which blazes from the center of Deity.

URANUS, HERSCHEL'S PLANET.

In man's works space is eliminated,
For it forms no barrier to his command;
He sends his message with good cheer freighted,
Receiving the touch of an unseen hand;
The Antipodes respond to his call
By saying that all on the earth is well;
Man marks his touch with the terrestr'al ball,
Yet far in the blue space his sight may dwell,
While toward the celestial spheres his thought may swell.

From time immemorial the inhabitants of the earth have been familiar with six of the planetary members of the solar system, including our globe. These were discovered so long ago in the remote ages of the past that no record of the event attaching to the finding of each planet has been preserved and transmitted to us. They were first noticed by those whose employment kept them out during the hours of the night. Under the clear sky in Asia or Egypt, the shepherds of the ancient world had ample opportunity to watch the panorama of the heavens. They took note of certain stars and observed that they were characterized by their fixity; while others were seen to change their places with reference to their neighbors. This latter class were denominated planets on account of their wandering propensities, as they shifted from one part of the sky to another. But the ancients, having no telescopes to aid them, failed to dis-

cover all the members of our great and interesting solar family; and so it became the good fortune of the modern age to discover the outlying planets which, though far off in the infinity of space, owe and render allegiance to the sun.

The discovery of Uranus marks an epoch in the science of astronomy, not solely from the fact that a new member was added to the system, but because it secured for the world the unrivalled services and efforts of a philosophical genius, with the name of whom many of the most profound discoveries and speculations in the realm of thought are connected. Apropos this statement, it is but proper that we insert a short biography of the life of Sir William Herschel; for, although he has been mentioned before in connection with different phases of the science, nevertheless the story of his life should be given in relating the history of Uranus, for his discovery of this great planet was a most prominent landmark in astronomy.

It is remarkable that so many of our greatest and best men spring from the lowest ranks of the people. Most of the mightiest thinkers and philosophers of all time date their birth to some humble home where they were trained in integrity, honor, and honesty. All praise to that home which, in addition to these virtues, inculcates in the minds of its inmates an insatiable desire for knowledge and philosophic truth. No higher ambition can inspire the mind of any man than the desire to bequeath to humanity some glorious discovery which will tend to elevate the race in the scale of being and of thought and action.

About six years after the birth of Washington, the patriot-hero and father of a new nation, William Her-

schel, he who added a new world to our system, first saw the light. He was born in Hanover, Germany. His father, an humble but accomplished musician, had a family of ten children, William being the fourth. This family, living their quiet and unassuming life, discussed together many subjects relating to music and philosophy, and every member of whom any record is kept showed his aptitude for music and his love for scientific truth. But none of them in later years rose to sublime heights but William, unless we except the little sister Caroline, who evinced her love for the true and the beautiful and became illustrious. William soon mastered all that his little school was able to give him, practicing music in the meantime, and at the age of fourteen or fifteen became so proficient in the art "common alike to angels and to men" that he was employed in the Court orchestra and also in the band of the Hanoverian Guards. Soon a wave of war swept the land. The French invasion and the skirmishes in which William was engaged became so distasteful to him that he decided to desert and seek his fortunes elsewhere. This act of desertion cast the one dark spot on his character; and it is said that twenty years after this, when he appeared before King George III to demonstrate an astronomical discovery, the King said that there was another matter which should be considered before a discussion might ensue, whereupon he handed to Herschel his pardon properly filled out and with the signature of authority.

The young musician by dint of industry and perseverence soon rose to a recognized station in the music realm in England, to which country he had gone and made his home. Before attaining the age of thirty,

Herschel was holding the position of chief organist in the Octagon Chapel at Bath, a city of gayety and pleasure. Here he was employed in giving lessons to his many pupils, and in arranging programmes for concerts and oratorios. But, even with all the happiness and pleasure which such work affords, his mind was still yearning for knowledge. His extra moments were employed in the study of higher mathematics that he might perfect himself in the more difficult and abstruse parts of the theory of music; later he devoted himself to the study of optics, which led him to the telescope and to a knowledge of its wonderful attributes with respect to the comprehensive science of astronomy.

The modest instrument through which Herschel obtained his first expanded view of the heavens was very small, but it gave him that feeling of awe and reverence which possesses one when first he contemplates the infinite: the stars in all of their lustrous beauty and splendor burst upon his sight and for a while overwhelm him with their grandeur; he stands, an atom in the infinity of being, and beholds the beauty and glory of the worlds. And, as Herschel thus gazed, he saw blazing out before him in an ever-widening highway of fame the path which he should follow—the path of glory unspeakable toward which his genius directed him. In this line of endeavor he might do something which would elevate the race and point it to a splendor that should dazzle and illumine the world. Soon he should abandon his concerts and oratorios, his pupils and pleasant associations, and commence the construction of telescopes and the grinding of specula and polishing of lenses. From his profes-

sional work as instructor in music he would return to his home and labor for hours on his telescope, which, fortunately for the development of the science of astronomy, he was compelled to construct, because he did not feel disposed to purchase an instrument at the prices quoted by the London dealers.

His renown as a laborious musician was soon to be eclipsed by his fame in the construction of telescopes and discoveries in the science of astronomy. When it became known that these discoveries were effected by means of instruments of his own construction, a demand for his telescopes arose, from the sale of which he realized some tangible results. He constructed in all between seventy and eighty large telescopes, and many small ones. This work in itself was of momentous consequence to the development of science. Herschel, in being his own instrument maker, enjoyed a great advantage, for he was thus able to see where improvements in the lenses or in their adjustment might be made. Everything was studied from the scientific point of view, with the object of adding any and every improvement possible and thus increasing the efficiency of the instrument.

After seven years' practical experience in astronomy, Herschel began a methodical observation of the heavens with a telescope of fine workmanship, which he had recently completed. We are ignorant of the motive which prompted him to examine all the stars above a certain degree of brightness. One star after another was brought into the field of vision and examined; all of these simply showed themselves as points of brilliant light, but not with a recognizable disc. As this task progressed, while examining the

hosts of stars in the constellation of the Twins, Herschel was struck with the appearance in his reflector of a star which differed from all of those hitherto examined. It presented not simply a point of light, but a disc, perfectly recognizable in shape and outline to the acute eye of the eminent astronomer. The star had been noted many times before, but the disc had never been perceived. The immediate recognition of the disc on the part of Herschel speaks an eloquent tribute to him as the ideal astronomer and observer.

For several nights Herschel observed the strange body, thinking that it was probably a telescopic comet. Soon, however, mathematicians began to calculate the path that the weird body followed, with the result that it was shown to pursue a nearly circular path around the run. This path lay millions of miles beyond the orbit of Saturn, and the body which pursued it was a giant planet coursing around the sun in a period of eighty-four years. Thus was another mighty member added to the solar system. At first it was named *Gorgium Sidus* after George III., King of England, but later, following the custom of the ancients in bestowing upon the planets the names of their heathen deities, it was called Uranus. This was the first recorded instance of the discovery of a planet, for the others, as we have said, were discovered in prehistoric times, and hence no record of the event.

Herschel now occupied the foremost position in the astronomical world. His name and fame were the theme of every tongue. The King listened with rapt attention as he explained the remarkable discovery, and the ladies of the Court gave him audience as he unfolded to them the marvelous wonders of astronomy

and showed them the unique construction of his telescope. The King gave him a position at Windsor so that he might devote all of his time and wonderful talent to the development of the science of astronomy. Many of the most profound theories were propounded and explained by Herschel as he assiduously devoted himself to the study of the heavenly bodies. He stands with Kepler, Copernicus, and Newton in the development of this comprehensive science.

Uranus, the massive planet discovered by Herschel, is about 31,700 miles in diameter, which is four times that of our earth. By cubing four, we find that Uranus is about sixty-four times the size of our planet, although he is only about fifteen times as heavy. This difference in his weight and size, when compared with those attributes of the earth and other small planets, leads us to infer that he is still in a semi-nebulous state like Jupiter and Saturn, probably retaining in great part his original heat. On account of his stupendous distance, plunged in the depths of space more than one and three-quarter billion miles, it has been found impossible to compute his period of axial rotation.

Uranus, like many of the other planets, is attended by a retinue of beautiful satellites, four in number. Sir William Herschel discovered them, making the number larger than subsequent research has averred, which indicates that he must have mistaken stars infinitely beyond the planet for satellites. One singularity about the Uranian system is found in the fact that the paths of his satellites lie in a plane nearly at right angles to the planet's orbit.

Uranus appears to be a star of the sixth magnitude.

Soon after the discovery of the planet in 1781, sufficient observations were secured to enable the mathematicians to determine his orbit; after which it was but a matter of calculation to ascertain what position the planet occupied in any time past, or what position he would occupy in any future time. Note of this fact was taken for the express purpose of determining whether Uranus had ever been observed and catalogued by astronomers who had such work under construction. It was found that Tobias Mayer, Bradley, Lemonnier, and Flamsteed had all observed the planet at one time or another. Lemonnier had observed the planet no less than twelve times, and recorded his position on four consecutive nights, thinking that each observation was that of a different star; but, had he compared his observations, he would have discovered that the star was changing his position with reference to his neighbors, by which he would have added a new planet to our system and anticipated Sir William Herschel.

In 1690, Flamsteed was making observations in that part of the heavens through which the planet was then passing. In his great work, the "Historia Cælestis," it was found that he had recorded a sixth-magnitude star, which was at once taken to be Uranus, for it was calculated that he occupied that precise position at the time indicated. What test was available to prove the assumption? The telescope was directed to that part of the sky where Flamsteed had observed the star. It was not there. Thus was it shown that the star observed was not a fixed star, which would still be there, but a wandering planet.

After a series of observations extending back to the

time when Uranus was first recorded, it was found that each revolution was made along a slightly different path from the previous one, and this perturbation of his orbit led to the conclusion that the planet did not move solely in consequence of the sun's attraction and that of the planets between himself and the sun. What, then, could account for these perturbations? The influence of the sun and of each of the planets upon Uranus could be calculated, but this did not account for the entire amount of perturbation attaching to his orbit. The only possible way to account for this difference in the orbital paths of the planet must be sought in the magnetic influence of some ultra-Uranian body. The circumstances attendant upon the discovery of this outermost planet we shall next rehearse.

NEPTUNE, THE OUTERMOST PLANET

When forever from our sight
Pass the stars—the day—the night,
Lord of angels, on our eyes
Let eternal morning rise,
And shadows end.

It now becomes our good fortune to relate the greatest intellectual feat in the annals of human achievemnt—the discovery of the planet Neptune by means of purely mathematical analysis alone. This massive planet appeared to the mathematician somewhat as the vision of America, the new world, arose to the sight of the inspired sailor. Sir John Herschel, in speaking of the marvelous event, said: "The planet's movements have been felt trembling along the far-reaching line of our analysis, with a certainty hardly inferior to ocular demonstration." In other words, the planet was known to exist long before the fact was confirmed by the observation of the telescope. How was this effected? To answer this question requires some explanatory effort on our part.

The law of universal gravitation reveals to us the fact that every body in the universe attracts and is attracted by every other body, and that the efficiency of a body as an attractive agent is directly proportional to its mass, and that the intensity of the attraction decreases as the square of the distance increases.

From this it may readily be seen that the stars in space on account of their tremendous distance exert no appreciable influence upon the planetary members of our solar system; and that the sun, whose mass is more than a thousand times that of Jupiter, who himself is larger than all the other planets combined, is the chief determining force in the movements of the members of our system. If we take the sun and his two largest planets, Jupiter and Saturn, we shall find that, although the sun is the chief determining force in the movements of the planets since they revolve mainly as a result of his attraction, nevertheless Jupiter perturbs the path of Saturn and Saturn perturbs the path of Jupiter, so that neither follows the exact orbit that he would pursue if it were not for the influence of the other. Thus it is that every planet in the system pursues a path perturbed to some slight degree by every other member of the system. This is such a complex problem that it gives rise to the question: Why may not these actions and reactions of the planets one upon the other cause great disaster to result to the system by drawing a body away from the sun or by elongating the ellipse to such an extent that at one period of its revolution the body would be subjected to extreme cold and at another to the extreme heat of the sun?

Lagrange and Laplace, eminent French astronomers who devoted themselves to the gigantic task of solving the problem of planetary perturbation, found that the planets are in no danger of having their orbits annihilated on account of their influence one upon another. Lagrange demonstrated that, notwithstanding the fact that the ellipse in which each planet moves

is perturbed or altered by other planets, yet the longest axis of the ellipse must ever remain unchanged; and, therefore, the mean distance of the planet from the sun which is one-half of the axis must also remain unaltered. Since this is true, and since the ellipticity of the orbit must ever remain small, we need never fear that the earth shall be perturbed from her path to such an extent that her inhabitants shall suffer from extremes of heat and cold; the seasons will remain approximately unchanged so long as the sun continues to supply us with abundant heat and light, and "seed-time and harvest shall not fail."

The harmony of our system might be completely annihilated if one of the planets were reversed and made to revolve in the opposite direction. The planets all revolve around their primary in the same direction, and, therefore, the planetary perturbations are not of such a nature as to threaten the destruction of the system with annihilating change. Its existence is firmly established.

In discussing the story of Uranus we alluded to the fact that it was impossible to reconcile the early observations of the planet's orbit and those made since he was found to be a planet. His perturbations were such as to lead the astronomers to believe that some outer planet was disturbing him in his orbit, and causing him to pursue a path slightly deviating from the one which he was calculated to traverse. The mathematicians were able to compute what disturbing effect each of the known planets was capable of producing. When all of these disturbing influences were summed up and applied to Uranus, it was found that they would not suffice to account for the irregularities which were

observed in his orbital path. The body causing the perturbations of Uranus, then, must lie beyond his orbit, for, if it lay interior to his path, it would long ago have been discovered. The sole data for the discovery of the new planet were simply the perturbations of his orbit. It was ascertained that his deviations could be explained by assuming that a certain body with a certain mass revolved in a certain orbit at a given distance from Uranus. No greatly altered conditions would satisfy the requirements and produce the necessary explanation of the planet's deviations.

Toward the middle of the last century, two eminent mathematicians, each ignorant of the other's efforts, set themselves to the task of solving the great problem. These men were the distinguished Professor J. C. Adams, of England, and the eminent mathematician, U. J. J. Le Verrier, of France. Each succeeded in solving the great problem, and the glory of the achievement must be equally shared between them.

Professor Adams soon after his graduation from Cambridge, in 1843, directed his attention to the perturbations of Herschel's planet, with the view of discovering the body which caused the deviations of Uranus from his path. He had nothing whatever to guide him in the search but the perturbations alone. He labored long and patiently, and, seven months before any other mathematician had arrived at a solution of the problem, he notified the Astronomer-Royal, in charge of the observatory at Greenwich, as to the position of the planet in the heavens, requesting him to direct his telescope toward that part of the sky and verify the mathematician's claim by ocular demonstration. The astronomer, not being in possession of a

star-chart at the time, delayed the search for a period of nine months. Professor Adams did not publish anything concerning his calculations.

In the meantime Le Verrier was arduously and assiduously employed in the task. In November, 1845, and also in June, 1846, announcements of the Frenchman's work were published, and then it was that the Astronomer-Royal observed that the mathematical calculations of Le Verrier coincided very closely with those of Adams. Immediately Professor Challis set to work with the great telescope at Cambridge to prepare a star-chart that he might be able to detect the planet among the hosts of stars in that part of the heavens indicated by the calculations. His purpose was to construct a chart and afterwards make the observations again, by a comparison of which he hoped to identify the wandering planet. It appeared that he observed the planet more than once, and, had he been given time to compare his charts, the planet must undoubtedly have been discovered by his methodical search.

Le Verrier in September, 1846, wrote Dr. Galle, of the Berlin Observatory, giving him his calculations and requesting him to make the telescopic survey of a certain part of the heavens for the purpose of discovering the new planet. Dr. Galle was in a position to make the telescopic search, for the Berlin Academy of Sciences had a few years previously made a series of star-charts, with every star to the tenth magnitude precisely located. These charts were being published at the time, and it so happened that the chart relating to the part of the heavens through which the planet was then wandering had been issued from the press shortly

before Le Verrier's letter reached Dr. Galle. All that was necessary to be done to discover the planet was simply to direct the telescope to the sky and make the comparison of the positions of the stars with their places on the map. Star after star was examined and its place on the map verified; but at length a star of the eighth magnitude was closely observed, and its place sought for on the map without avail. This body was not in that part of the heavens when the map was constructed, therefore it must be a wanderer—a planet. It behooved the astronomers to progress slowly and carefully, for it might be a minor planet coursing between the orbits of Mars and Jupiter, or it might be a variable star which at the time when the chart was made was too dim to be recorded, but had since increased in brightness to such an extent as to be a brilliant object. On the next night the planet had changed its position with reference to the stars, and was coursing in the precise orbit that had been embodied in the theory of Le Verrier. This was the planet, indeed; the disturbing force which had perturbed the orbit of Uranus, occupying almost the exact position pointed out by Adams and Le Verrier, the calculations of whom varied not more than one degree from the place which the wandering orb claimed as its transient abode! This intellectual achievement was without doubt the greatest triumph that had ever come to the mind of mortal man—the Newtonian theory of universal gravitation had been verified beyond the probability of doubt.

The French were enthusiastic over the achieved distinction of their eminent mathematician; but it has now become recognized throughout the world that the

distinguished Englishman is entitled to as much honor, and so it is bestowed upon both. Each had accomplished a feat unparalleled and unapproximated in the annals of scientific research; each had plunged into the depths of space to an appalling distance, and yet in this dim cavern he had discovered truth.

The new planet was called Neptune after the Roman god of the sea. His mean distance from the sun is about 2,790,000,000 miles, and it takes him nearly 165 of our years to complete one revolution. His diameter is about 35,000 miles; but his period of axial rotation is unknown. The density of the planet when compared with that of the earth is very low, which, supplemented by the fact that he is enveloped in a cloud-laden atmosphere, leads us to infer that he is in a nebulous or semi-nebulous state, possibly retaining in great part his original heat. His velocity along his orbit is not much more than one-sixth the velocity of the earth; this is acounted for by his stupendous distance from the sun.

Neptune is attended by one satellite, which completes its revolution around the planet in a period of nearly six days. The weight of Neptune, as determined by observing the influence which he exerts upon his satellite, is about the nineteenth part of Jupiter's mass; or, by another comparison, it would require about 19,000 globes as heavy as Neptune to equal the weight of the sun.

The astronomers are ignorant as to the existence of any ultra-Neptunian planets. For aught we know, small planets may exist beyond the orbit of Neptune; but it is scarcely within the range of feasibility to believe that they may be readily detected, on account of

Neptune and His Satellite.

(XII., p. 142.)

their stupendous distance. We have seen that the numerous minor planets have been discovered; but these were found in the belt of space lying between Mars and Jupiter. If planets of any consequence lay beyond Neptune, they might be discovered by the same methods which the astronomers now employ in their search for minor planets; but their efforts have not as yet resulted in the detection of any body beyond the orbit of Neptune. After Neptune has traversed his orbit for some time, for he has covered only a part of it since his discovery, it will then be seen whether or not he is subjected to any ultra-planetary influence; and, if he is perturbed from his path more than the sum total of the interior planetary influence will verify, it will be assumed that he is perturbed by some extraneous body, which may be discovered by mathematical analysis, even though it may never be confirmed by ocular demonstration.

Neptune, then, so far as we know, forms the exterior boundary of the solar system. His discovery, founded on the profundity of theoretical learning, was an achievement of the modern age; while the discovery of Mercury, the planet forming the interior boundary of the solar system, was an event dating so far back in the hazy distance of the past that no record of the event has been transmitted to us. Between the orbits of these two planets are encompassed the remaining members of the system which owns its allegiance to the great sun in the center. Besides the planets and their satellites, there are still other bodies which swing about the sun and do homage to his majesty. The comets and meteors proclaim his royalty and aver their fealty to his kingship. The entire system is a marvel

of beauty, proclaiming harmony throughout its every part, and demonstrating the great Power which moves beneath the material worlds.

COMETS, THE GHOSTS OF NIGHT

Go, tell the Night that hides thy face,
Thou saw'st the last of Adam's race,
On Earth's sepulchral clod,
The darkening Universe defy
To quench his immortality,
Or shake his trust in God!

The stars and planets are the ponderous orbs of space, while the comets are of a thin, filmy, flimsy nature, dashing through space with the apparent lightness of a feather or the down of the thistle. The mighty sun and his attendant planets have been weighed, but every effort at determining the mass of comets has proved abortive. The planets possess an orderly movement which enables us to foretell with accuracy the positions which they may occupy at any future time; but the comets without any warning whatever dash into the solar system and blaze forth with their long tails to the terror of the ignorant and the superstitious. We of the present age do not attach so much grave importance to the appearance of comets as did the ancients, because we understand them somewhat better than did our ancestors of the gloamy past. At least, we have concluded that there is nothing to fear from them; they are pleasing and interesting visitors, which come to entertain and to instruct us, but never to threaten or cause disaster.

During the remote ages of the past, when the barbarians would descend upon our progenitors and plunder and outrage them, they would invoke the Divine aid against the marauders, always including in

their prayer the other horrible enemies who brought disaster and destruction upon them: "Good Lord, deliver us from the Devil, the Barbarian, and the Comet!" But it is needless for us to fear or consider a comet as a portent of evil. We might gaze upon it with such a feeling of reverence as that which possessed Hamlet when he looked upon the Ghost; but even then we need not fear it. When his friend besought him not to follow the Ghost, Hamlet, with the deep spirit of the philosopher, replied:

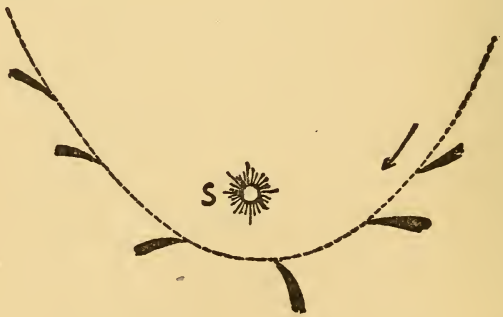
> "Why, what should be the fear?
> I do not set my life at a pin's fee;
> And for my soul, what can it do to that,
> Being a thing immortal as itself?"

Since comets appear in such a variety of forms, sometimes with a long tail and then again with none, ever changing their position and shape, it is impossible to identify them by photographs or drawings when they return to our part of the universe. This is accomplished chiefly by a knowledge of their periodicity and the orbits which they traverse. The nucleus or head of a comet, which may range in diameter from a few thousand to a million or more miles, is enveloped by the coma, from which the tail streams away. Those comets which belong to our system make periodic returns, but their personal appearance may change from time to time, so that at the return of any comet it may not be so bright as before or its tail may be less or entirely wanting. But, notwithstanding the changed appearance, the laws of Kepler enable us to identify with absolute precision, for comets, like planets, obey the laws of elliptic motion.

The comets which dash into the solar system from the infinity of space never return, because they follow parabolic curves. The parabola is a geometric figure, the curve of which bends in toward and around a certain point known as the focus. We might comprehend the paths in which the comets make their journey if we were to imagine a series of ellipses drawn with the foci of each succeeding one placed wider and wider apart, until their distance had become enormously great in comparison with the distance of each focus from the curve forming the figure, for we should then have an ellipse each end of which resembled the form of a parabola. But there is an obvious distinction between what is termed parabolic motion and elliptic motion, the difference being found in the fact that, when a body follows an ellipse, it must necessarily pass the focus at aphelion and return to perihelion, thus establishing a periodicity; but, in the case of the parabolic curve, the return to perihelion would necessitate the doubling of the distant focus, which, since it is infinitely remote, could not be accomplished until the lapse of an infinite period of existence. The comet swinging in a parabolic curve draws in gradually toward the focus, after the passage of which it moves off on the other side, receding to an infinitely remote distance in the infinity of space.

The velocity of a comet increases as it approaches the sun, sometimes dashing around that body 20,000 times as fast as an express train, or 1,000 times as fast as the swiftest rifle bullet. As the body recedes from the sun, its velocity decreases, becoming less and less until aphelion is reached, when the sun again assumes ascendency over the comet and begins to draw it back

to himself with an ever increasing rate of speed until at perihelion the maximum velocity is attained. If the comet moved from a position of rest, it might dash into the sun; but, since it never entirely stops its motion, it is made to pass around the sun with an ever accelerating rate of speed, which gives it the required impetus to send it forth on its long journey into limitless space. This action of the comet might be better conceived if we compared it to the motion of a suspended weight which is drawn to one side and then let swing to and fro; instead of stopping at the center of gravity, it swings far to one side and then to the other, keeping up the motion for a considerable length of time, but ever becoming slower, while the comet has its speed again accelerated every time that it passes the sun.



COMETS TAIL – FROM THE SUN

appendage, but, as it approaches the sun, the engendering heat of that body causes gaseous substances to

Far out in space the comet is not adorned with an

Halley's Comet.

(XIII., p. 149.)

emanate from the nucleus in such a way as to form a tail, which continually increases, following behind the comet, until it passes the sun, when the tail precedes the comet and becomes continually shorter until it finally disappears. The disposition of a comet's tail is always from the sun. The spectroscope has shown that the cometary materials entering into the composition of the tail are chiefly carbon, iron and sodium.

The tail of a comet, although thousands of miles in thickness, can not obscure the smallest star. Even the nucleus or head is sometimes so transparent that the twinkling, sparkling light of a star is transmitted without much decrease in its brilliancy. The merest cloud a few feet in thickness will obscure not only the stars, but the great and mighty sun himself. The thinnest fleece of cirrus cloud that floats in the azure blue far above the surface of the earth will do more to dim the luster of a star than 100,000 miles of cometary matter in its hazy and attenuated condition. Not infrequently, when a comet passes between the earth and the sun, our little planet is engulfed in the tail of the comet like a pebble or a shell in the waters of the deep. This might be deleterious to us, were it not for the protection offered by our atmosphere, which acts as a great shield or blanket to prevent injury from noxious gases or meteoric particles.

Of the periodic comets which owe allegiance to the sun, and do homage to him by returning at stated intervals, Halley's Comet is perhaps the most significant. When this great comet appeared in 1682, the illustrious astronomer Halley discovered that it moved in an elliptic orbit, from which he knew that it must of neccessity be periodic. When before this, then, had

it visited our system? To find an answer to this question Halley consulted the list of recorded comets which he had carefully compiled, and he found that the comet then in question closely resembled one which had appeared 75 years previously, in 1607, and another which had been seen in 1531, and that it followed very closely the orbits of these two bodies. Other comets were recorded as having appeared at intervals of 75 or 76 years, and from this Halley concluded that they were but returns to perihelion of one and the same body. He submitted his belief to a supreme test by predicting that about 1758 or 1759 the comet would return again. He showed that the comet might be delayed by being perturbed by the great planets of the system, but that its return would be about the time indicated in his prediction. The great astronomer knew that his earthly pilgrimage would be run and his good fight fought long before the remarkable event should occur, and hence he besought posterity not to let his name and fame be forgotten, but to accord him the honor of having made the wonderful prediction and of having gazed across the three-quarters of a century.

As the time for its reappearance drew near, a distinguished mathematician, Clairaut by name, by means of improved methods, began anew to compute what influence the planets of our system would have in perturbing the comet from its path and delaying it beyond the anticipated time. He showed that Saturn would delay the comet about 100 days and Jupiter about 518 days. On Christmas Day, 1758, the comet was first seen, and it passed perihelion on the 12th of March the following year, which did not deviate far from

the time predicted by Halley and amended by Clairaut.

Seventy-five years later, in 1835, the comet returned again, followed this year, 1910, by another reappearance. It has gone away on its journey extending millions of miles beyond the orbit of Neptune, and will not return again until three-quarters of a century shall have elapsed. On these returns it passes between the earth and the sun, and its tail stretching away millions of miles completely envelops the earth as in the meshes of a net.

There are other periodic comets, chief among which are Encke's Comet, Biela's Comet, and Winnecke's Comet. Observations disclose the fact that the period of Encke's comet, which completes a revolution in a little over three years, is inconstant. Backlund has accounted for this inconstancy by propounding the idea that the minute body sometimes encounters a swarm of meteors, which cause the delay in its periodic return. By means of these comets the astronomers are able to verify the weights of the sun and planets as obtained by other modes of research.

During the last century, great comets have appeared in the years 1843, 1858, 1880, 1881, 1882 and 1892. They appear in the most diverse circumstances and in any part of the heavens, no constellation being free from their occasional and ghostly visits. They range in apparent size from the great comet seen in broad daylight, with a tail extending from the horizon to the zenith, thus apparently spanning ninety degrees of the visible universe, to the dim spot seen only by the eye fortified with the mightiest telescope. Not infrequently telescopic comets resemble vast nebulae lying far off in the hazy distance of space, but they

can be distinguished therefrom by their onward motion with reference to the stars; the comets change their position with remarkable celerity, while the stars and nebulae remain unchanged for centuries. The comet may sometimes be actually seen gliding among the stars with its silent ghost-like form, as if fearing lest it should make a noise and terrify the sentinels of night. If, as the poet says, the stars be the lamps of the angels, the comets might to the superstitious be symbols of the inverted torch.

It seems that in the case of periodic comets the tail decreases with each return of the visitor to perihelion. We might assume that the comet began its journey with a given supply of tail-producing material, and that every time it passed the sun a certain amount of this was expended; in the lapse of time the comet would exhaust all of its material and thus would be incapable of producing an appendage, and we should then have a comet without a tail. In this manner a comet may be completely dissipated and all trace of it forever lost. It seems that such a fate has befallen Biela's periodic comet.

If, in sweeping among the planets of the solar system, a comet should have its path so perturbed by a large planet as greatly to accelerate the velocity of the moving body, it would then be diverted from its course; and, instead of pursuing a parabolic orbit, its path would be transformed into a hyperbolic curve, which it would follow around the sun, passing away never to return. But, instead of accelerating the velocity of the comet, the planet might be so situated as to retard its speed, in which event the parabolic orbit would be transformed into an ellipse and the

comet would become periodic, thus returning to the sun, or perihelion, at given intervals. It is not too much to say that comets have escaped from our system in the manner above indicated, while, on the contrary, others have been captured and made permanent members of our solar system, obeying the same laws of elliptic motion by which the planets are controlled.

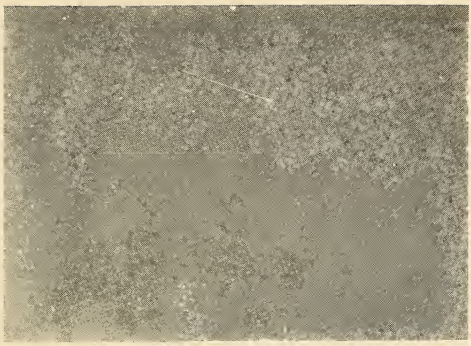
Comets, like innumerable other mysteries, are not thoroughly understood by us, nor shall they ever be; but they teach us a lesson as to the mystery of life and its potentialities by obeying in every detail the law of universal gravitation with the same exactitude as the mighty planets, thus demonstrating that there is nothing higher or nobler than truth and the demands made by Divine authority. A decree of law goes forth from the throne of the Infinite, and every atom in the universe of God is constrained to obey it or suffer the penalty of disobedience. This law is universal, primordial and immortal; it is the law of infinite truth. The inanimate worlds obey it; should man, the zenith of creation, do less?

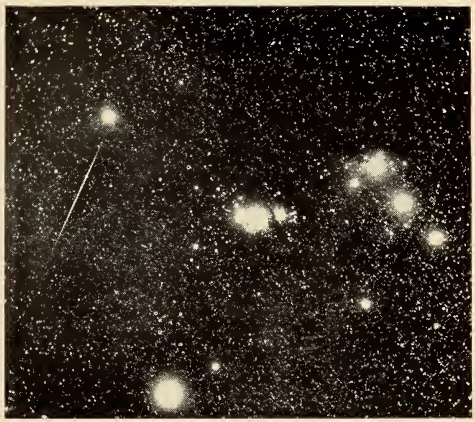
METEORS OR SHOOTING STARS.

Aurora, in her gilded car,
Threw up the golden spray afar;
The blazing of her horses' eyes
Reached far up in the purple skies,
While panting of the steeds she drove
Blew out the lamps that burned above.

From a consideration of the great and mighty globes of the solar system, and the swinging satellites and evanescent comets, we come now to study the smallest bodies which recognize the controlling influence of the sun. Every object, whether it be so small as a grain of sand on the sea shore or as massive as the mighty Jupiter himself, must trace its orbit around the sun with the same exactitude and precision. The great law of universal gravitation is obeyed by all alike, from the smallest speck that floats in the infinity of space to the mightiest sun that shines in the depths of heaven. The meteoric bodies shine only at the moment of their destruction. For countless ages the meteor wends its flight unmolested through the emptiness of space, but the supreme moment arrives when it encounters the atmosphere of the earth, and it then perishes in a flash of brilliant light.

In the days of innocent childhood we are told of the judgment and destruction of the earth, and we are





1. Meteor Trail with Pleiades in Feld.

2. Meteor Trail in Constellation of Orion.

(XIV., p. 154.)

also told that the stars are worlds; so at night, when we see a meteor burst into a ray of splendor, we are at once impressed with the thought that a world has been judged and destroyed. But, when we come to understand the true nature of the shooting star, we know that it is not a mighty globe, but simply a particle dashing itself to destruction against the shield of atmosphere which protects the earth. The meteors may be considered as darts hurling themselves with prodigious force against the atmospheric shield or armor-plate enveloping the earth.

The reason why sufficient heat is generated to consume the object is because of the tremendous velocity at which the meteor is moving. This rate of speed may be more than twenty miles per second, or more than one hundred times as fast as the swiftest rifle bullet. Now, bearing in mind the two-fold fact that the meteor is flying enormously faster than the bullet and that friction develops heat proportional to the square of the velocity, we can readily understand that the meteor may in a few seconds rise in temperature to such a degree as to be completely driven off in the form of vapor. If the bullet rose one degree in temperature and the meteor dashed one hundred times as fast, we should have to square one hundred, obtaining ten thousand, to account for the number of degrees which the meteor would attain in the same moment of time. Of course, the temperature could never rise so high as that, for any and every substance known would melt and even be driven off into vapor long before heat so enormous was produced.

At times the telescope reveals numberless shooting stars too small to be visible to the unaided eye. We

never know of their existence until the moment of their dissolution, when they burst into a streak of splendor and perish forever. They are luminous only in death. Were it not for the benign influence of our atmosphere, they would probably render the earth uninhabitable, for they would pour down upon her with prodigious force and velocity far transcending the production of any artillery known to the art of man. It is this enormous velocity which saves us from destruction; for, were they traveling at a slow rate of speed, the friction would not be sufficient to engender enough heat to cause their dissipation, and they would then rain upon the earth, occasioning vast destruction and ploughing up the surface. The eager swiftness with which they attempt to attack the earth is the feature alone which prevents their malicious design from having the desired effect, and dissolves them into harmless vapor. The earth absorbs the meteors, and thus no harm ensues as a result of their contact with her in crossing her orbital path.

A single meteor flashing across the sky is a striking spectacle, but a shower of them is still more pleasing to behold. We have about twelve recorded instances of meteoric showers. They appear, in the case of the Leonids, to have an interval of about thirty-three years, and the shower generally accurs in November. In 1833 a beautiful shower took place, and again, in 1866, thirty-three years afterwards, a repetition of the phenomenon occurred. It was expected that, in 1899, the glorious spectacle would again be observed, but only a few straggling meteors, such as may be seen at almost any time, greeted the sight of the spectators as they gazed toward the heavens, and but few of these

seemed to emanate from the point characteristic of the Leonid shoal. The reason why no meteoric shower occurred in 1899 is attributed to the fact that the shoal, although approaching very close to the earth's path, did not come in direct contact with her. The shoal is of such enormous length that all of the meteors cannot escape the earth. They are scattered about such a long orbital path that, when the earth passes through one end of the shoal one year, she may pass through the other end the next year, for the entire shoal may not yet have passed, and a few lingering meteors may be again seen. This is why, in 1866, such a beautiful display of meteors was seen in the old world, followed the next year by a splendid display visible to the American continent. In the former instant, at the hour when the earth plunged into the meteoric shoal, the Eastern Hemisphere happened to be in the van of the movement, and the shooting stars were seen from the old world; whereas the next year, when the earth had regained the same position, the shoal had not entirely passed, and thus the earth plunged into it again, with the new world in front, from whence the display was then seen. A few are observed every time that the the earth crosses the path of the shoal.

Another beautiful meteoric shoal, called the Andromedes, is encountered about the time in which the earth is crossing the orbit of Biela's Comet. Since the comet has become dissipated and divided into fragments, it is believed that some relation exists between it and the shooting stars. The comet has not been seen for more than half a century, at which time two fragments were pereceived; but on several occa-

sions since, when the time for its reappearance had arrived, showers of meteors were seen. The shoal seems to follow the same orbit formerly pursued by the comet, from which we infer that some vital relation must exist between the two phenomena.

Numerous as the meteoric showers have been, not one particle from the myriads of missiles projected from the radiant of the Leonids, the Andromedes, or the Perseids has ever been found and identified. Astronomers have now come to believe that the bodies which we call meteorites do not fall from the great showers, but possess an origin altogether foreign to that which characterizes the periodic meteors. The meteoric showers revolve in paths pursued by dissipated comets, and the shooting star particles very probably derive their existence from the comet; but, although showers of shooting stars have some probable connection with comets, it would be error for us to associate meteorites with comets, since it is found that no meteoric particles have been averred as falling from the showers.

To understand the theory of the origin of the meteorites, a study of their composition and structure may be necessary. It was formerly doubted that masses of rock fell from the sky, and the specimens accumulated were deposited in the department of geology in the museums; but, since the falling of meteoric particles has been verified, the specimens have been placed in the astronomical division of the science halls. These range in size from minute particles to masses

weighing several hundred pounds. If it were possible for the meteorite to relate the story of its existence, it might give us a marvelous tale of its wanderings in the realms of space. The questions which we should like to have it answer for us would be with respect to the place of its origin, where it was ages in the past, the size of its orbit, what bodies have influenced its course, and what has caused it to be deposited on the earth. When we analyze these bodies, we find that some of them are composed of almost pure iron, also an alloy of iron and nickle, while others are composed of stone and several mineral substances. In the minerals and rocks of the earth we are more or less familiar with the substances which compose the meteorites, and we find them identical.

A tremendous noise frequently ensues as a result of the explosion which takes place when the rock mass becomes enveloped in the atmosphere. When the explosion takes place, fragments of rock are generally scattered over the vicinity above which it occurs; but it is recorded that detonations have been heard without any deposits being found as a result of the explosion, the fragments being too small to be accumulated, or passing entirely off into meteoric dust.

For the purpose of solving the mystery attaching to the origin of meteorites, Tschermak, the Austrian mineralogist, proposed the theory that the meteorites have been ejected by volcanic force from some celestial body. The question arises: From what body or bodies have the meteorites been ejected? Astronomers and mathematicians have speculated and calculated in order to give a truly scientific solution, fulfilling all the conditions involved in the abstruse problem.

Terrestrial volcanoes frequently hurl prodigious rocks to an appalling distance; but it matters not how for the particles ascend, the volcanoes are not now powerful enough to send them sufficiently far that the gravity of the earth will not draw them back again. The higher any body ascends above the earth the weaker becomes the force of gravity, so that the difficulty of recalling the body increases in a two-fold way. But the critical velocity of the earth, as we have seen, is six or seven miles per second, so that no terrestrial power, either natural in the form of volcanoes, or artificial in the form of artillery, is capable of producing a velocity sufficient to hurl a projectile beyond the control of the earth. Tschermak's hypothesis, therefore, would not at present apply to the earth, because the initial velocity required is too great.

Would it apply to any other body? We cannot see volcanoes on the other planets, but mighty craters are to be observed on the moon; and, since she is so much smaller than the earth and her critical velocity so much less than that of our globe, being only a little more than a mile per second on account of the lessened force of gravity, it might be appropriate to regard that body as the parent of the meteorites. A fragment of rock hurled from the moon would, in accordance with the laws of Kepler, move around the earth as a focus, and, if once the meteorite missed the earth, it would never thereafter strike her, unless perturbed from its orbit by some other body. Thus, for the lunar projectile to reach the earth, it must do so shortly after its ejection from the moon; and, since the lunar craters have long since ceased to be active, no projectiles are at present hurled from that body, and, therefore, the lunar theory

does not satisfy the conditions of the problem.

Nor will the large planets, like Jupiter and Saturn, fulfill the conditions of the problem, because of the tremendous initial velocity required to send a mass away never to return. The critical velocity being so great, it would be beyond credulity to assume that a volcano could eject a fragment of rock with force sufficient for it never to be recalled by gravity. The minor planets may also be dismissed, for the reason that a projectile hurled from one of them would have to pass through the narrow orbital path of the earth, a circle only 8,000 miles wide; and, if the earth were there at the time, the meteorite would come in contact with her, and thus perish in a streak of splendor and beauty. Therefore, even with the low velocity which it would require to hurl into space a projectile never to return, it has been estimated that, where one meteorite struck the earth from this source, thousands would not reach her at all—the odds having been estimated as 50,000 to one. What body, then, in all the system has the greatest probability in its favor as being the source of the meteorites?

We may find the answer to this question near at hand, if we consider that our earth was in remote ages vastly superior in heat to what she is at present. It seems that in the early days of geological time the volcanic activity and energy of our earth was for more powerful than any force of this later day. With many difficulties to overcome in our course of reasoning, we may assume that in the primeval days of volcanic activity mighty throes hurled forth rocks with such tremendous violence and velocity that the gravitation of the earth was unable ever to recall them, and that the

sun began to exercise control over them so that they swung around him as their center. To be sure, the resistance of the earth's atmosphere would be an obstacle to surmount, but this might be eliminated to a degree, if the crater were high above the earth's surface and a volume of steam and vaporous gases accompanied the projectiles as they sped onward in their signal flight. If any swung in hyperbolic curves, they would dash away never to return; while those that were constrained to follow elliptic paths would swing ever around the sun, crossing at each revolution—and this is the point to consider—that part of the earth's path which she was traversing at the moment of their ejection. Each meteorite, then, during every journey around the sun must pass through the earth's path; and, if she should again at that moment be journeying there, the meteorite would dash into her atmosphere and be destroyed, or in rare instances it would fall to the ground.

Assuming this to be the correct theory with reference to the meteorites, we must conclude that there are numberless myriads of these little bodies coursing round the sun, each crossing the earth's path during every revolution, while she herself is bringing to an end the journeys of the little bodies and taking them back to herself from whom they were driven so many ages ago. The earth is gathering in her harvest, and becoming imperceptibly larger each year as a result of the meteoric dust deposited on her surface, which, for aught we know, may have been in greater part thus formed throughout the hazy epochs of the past.

When the earth, dashing along at the rate of eighteen miles per second, and a meteorite, traveling

Constellation of Orion.
(Exposure 30 minutes.)

(XX., p. 162.)

Nebula in Andromeda.

(XVIII., p. 163.)

faster still, meet, the little body is completely destroyed, the earth claiming its ashes; but, if the meteorite rushes in behind the earth, the velocity with which it strikes the atmosphere is simply the difference in speed between the two bodies, and may not be more than a few miles per second, in consequence of which the meteorite, not destroyed by friction, may fall to the ground. This, in brief, seems to be the mode by which the meteorites find it possible to land upon the earth.

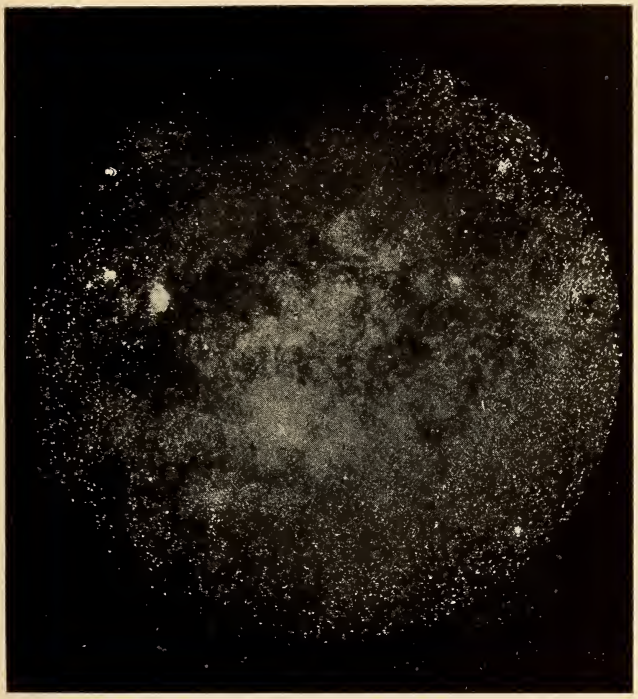
The shooting stars, therefore, are mysterious in their action, and supply us with food for profoundest thought; for there is a world of philosophy in a meteor as it bursts upon the earth in a ray of dazzling splendor and beauty, eliciting from every observer an expression of deilght.

THE SUNS IN SPACE.

But the day is spent,
And stars are kindling in the firmament,
To us how silent—though, like ours, perchance,
Busy, and full of life and circumstance.

For us thoroughly to understand the positions of the principal constellations, we should supply ourselves with star-maps or charts, by means of which we may become familiar with the stars and their places during each month in the year; because, on account of our annual passage around the sun, there is an apparent change with reference to the position of the stars. Eliminating the few planets which we may see, all the beautiful gems which glitter in the firmament are suns like our own, many of them probably transcending him in magnitude and brilliancy. And, besides these, there may be myriads of lifeless bodies, that is, bodies which have lost their original heat and are now dark and invisible. Whether or not these bodies are the abodes of life in any form is a matter of uncertainty and speculation. On account of the Cimmerian darkness and the intense cold which must ever prevail on these bodies, life as we know it on earth is impossible.

Sirius, the brightest star in the heavens as viewed from the earth, and over twice the mass of our sun,



Star Clouds in Milky Way.

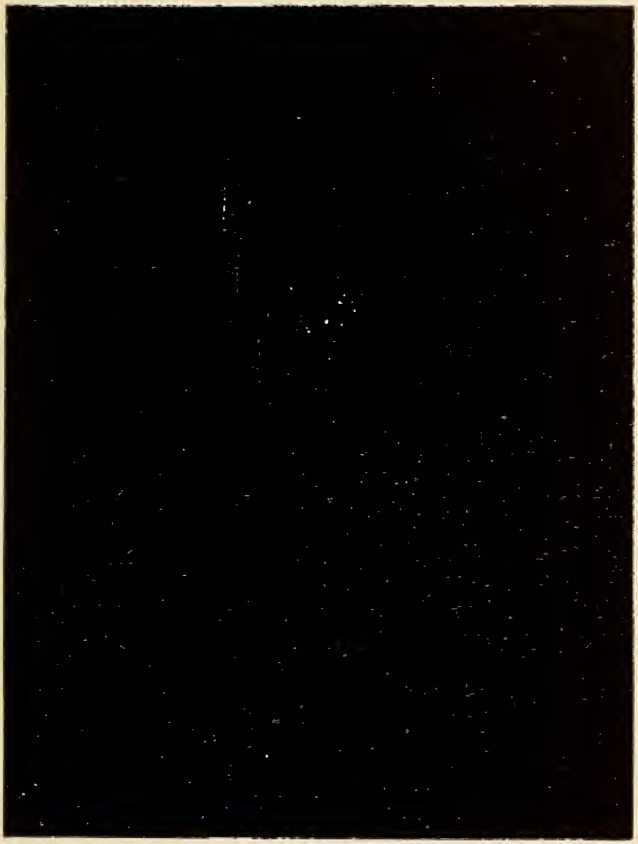
(XXI., p. 164)

is attended by a companion slightly heavier than our luminary, and yet so devoid of light that a hundred bodies like it would not equal the brilliancy of the sun. Sirius as viewed from the earth is 5,000 times as bright as his companion, but only about twice as large. It is a well conceded fact that numberless orbs of space possess no light at all, which leads us to infer that, as "all that tread the globe are but a handful to the tribes that slumber in its bosom," so the visible stars may be but a small part of the great numberless host that lie invisible in the somber shades of night. Comparatively speaking, probably only a few stars or masses of gaseous matter retain their original heat to such an extent as to be visible from the earth as a result of their luminosity.

The most important star in the northern heavens is the North or Pole Star. It remains ever above the horizon, approximately in the same position, and encircles the pole of the heavens. The constellation of *Ursa Major,* or the Great Bear, often called the Dipper, contains the two pointers which direct the observer to the Pole. There are many famous constellations, the positions of which may readily be observed by the use of a star-map. On the opposite side of the Pole Star from the Great Bear may be seen the beautiful constellation of Cassiopeia, so called in honor of the wife of Cephus, a fabulous king of Ethiopia. Near by is Andromeda, the daughter of Cassiopeia. By command of the Oracle of Ammon she was chained to a rock to be devoured by a sea monster, but Perseus, the lengendary hero, killed the monster and rescued the unfortunate girl. A constellation in the same neighborhood has been named for the hero.

Many of the constellations are named from the characters of ancient mythology. The interesting Square of Pegasus received its name from a certain winged horse of the Muses, which sprang from the blood of Medusa when she was slain, and with one blow of his hoof caused Hippocrene, the famous fountain of the Muses, to gush forth from Mount Helicon. Bellorophon is fabled to have ridden the furious charger when he slew the terrible Chimera; but, when the hero made an effort to ride the horse to heaven, he threw him off and ascended to the skies alone, where he was transformed into a constellation. Then we have the beautiful constellation of the Pleiades, or Seven Sisters, so called from the seven daughters of Atlas and the nymph Pleione, fabled to have been placed in the skies by Jupiter. Only six of the pleiads are distinctly visible to the naked eye, which led the ancients to believe that the seventh sister had concealed herself as a result of shame for having loved a mortal, Sisyphus.

It is interesting and instructive to study the numerous constellations, and discover why they were so named; and the numberless stars of the several magnitudes are fraught with so much of beauty and grandeur that we may well engage our attention in learning to locate their positions with reference to one another. Among the myriads of stars and numerous constellations are many double and variable stars. The double stars revolve around their common center of gravity, and, if planets attend them, how wonderful it must be to have two suns in the sky at once, one



The Pleiades.

(XVI., p. 166.)

Great Nebula in Orion.

(XVII., p. 167.)

apparently passing the other, or one on either side of the planet, giving it day over its entire surface! Many of the double stars are vari-colored, some of them blue and others red. What a wonderful variety of tints would be made when two suns were shining together in the sky and illuminating the scenery of a planet! How fascinating the satellites of such a planet would be, as they reflected the resplendent light of the suns!

The variable stars are those which glow with wonderful brilliancy for a certain period and then lapse back into their previous condition, many of them passing through this cycle indefinitely. Not infrequently a star hitherto invisible flares out with wonderful brightness, but to wane with correspondingly marked abruptness. In the case of some variable stars, for instance, Algol, the light is intercepted by the passage of a dark companion between the observer and the star, which causes it to appear to decline in brightness at certain intervals, that is, during the period of the passage. It is intensely interesting to follow a star through the periodic variable changes which mark its increase and decline.

These gigantic suns are separated from us by exceedingly tremendous distances, by abyssal gulfs of space. Alpha Centauri, one of the nearest fixed stars, is estimated to be at least 20,000,000,000,000 miles from us—a distance so appalling that the light from the star requires three years to reach the earth, although flashing at the rate of 186,000 miles per second; or, in other words, the light which we now see

left the star three years ago. It would require several hundred years for one to count the distance in miles to the star, while it has been declared that all the cotton mills of the world combined have not as yet spun a thread of yarn long enough to reach it! The South in half a millennium might grow cotton sufficient to produce a thread adequate to span the tremendous gulf which separates us from our nearest stellar neighbors! If one were to make a journey to the nearest star, traveling 10,000 miles for one dollar, it would require $2,000,000,000—double the value of our present cotton crop—to purchase his ticket.

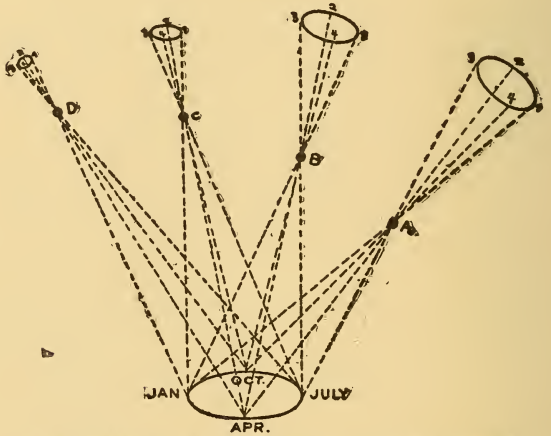
The nearest stars are so far from the earth that their light must require several years to reach us; but there are stars at every conceivable distance, and the time required for the light to reach the earth from them varies from a period of years to centuries, and from centuries to millenniums, and from millenniums to ages. If we could see the real structure of these remote stars, we should not see them as they are at present, but as they appeared years ago when the ray of light now entering our eye left them. On the other hand, if the inhabitants of those distant worlds could see our earth, they would not see her as she appears to-day with her mighty hives of industry and of thrift; but they would see her when the terrible Civil War was raging, or when the mighty whirlwind of the French Revolution was overturning the thrones of Europe; while those more distant would look upon her as she appeared during the Mediaeval Ages, or

when Greece and Rome were at the zenith of their power and prowess, or when Moses led the children of Israel out of bondage, or when the Ark floated upon the bosom of the deep and rested on Mount Ararat; while still there are other globes so far engulfed in the depths of space that the earth would present to them the view of an intensely heated nebulous mass floating like a bright mote in the hazy dust of the geological past. Truly we may exclaim with the poet:

"Set in the boundless realms, they say,
There are fixed stars, so far away.
That, if some power should veil their face,
Their light would still shine on through space,
And we on earth should never know
That the stars had ceased to glow."

The revolution of the earth around the sun enables the astronomers to approximate the distance of some of the stars. We are aware that in her passage around the sun the earth in any season is 186,000,000 miles from the position occupied by her six months previously; that is, twice the distance from the earth to the sun, which is the diameter of the earth's orbit about her primary. The stars, on account of this passage, undergo an apparent change with reference to their position on the background of the sky. We, oblivious of our own motion, which produces the apparent displacements, attribute the changes to the stars themselves. This change in apparent position is termed the annual parallax of the star, the orbit of the star being denominated the parallactic ellipse, the major axis of which being measured, the distance from the star to the sun, inversely proportional to the size

of the ellipse, is determined and expressed as a multiple of the earth's radius. The nearer a star is to us, the larger is its parallactic ellipse; while, conversely, as the stars recede into the abyss of space, their parallactic ellipses become smaller and smaller, approaching



THE DIFFERENCE IN THE PARALLACTIC ELLIPSE ACCORDING TO THE DISTANCE OF THE STAR

the infinitesimal and imperceptible. The diagram shows the position of the earth for the several seasons, and illustrates the difference between the apparent ellipses of a star comparatively near and one more remote in the azure depths. The greatest difficulty in measuring the distances of the stars is attributable to the smallness of their ellipses, the great majority of them being so minute that the micrometer often fails to detect them.

Region of Milky Way.

(XIX., p. 171.)

Although the stars appear to be fixed, there is no doubt that they are traveling with tremendous velocity. Even in a century their apparent position changes but little. It is computed that 61 Cygni, one of our nearest stellar neighbors, although about 40,000,000,000,000 miles from us, must move at the rate of at least thirty miles per second; but, even traveling nearly one billion miles during a year, its proper motion in that period is only five seconds of arc, an amount so insignificant that the untrained vision would hardly detect it in a century. If the star be moving toward the earth—toward the solar system—40,000 years must elapse before the neighbors shall greet each other! Thus the stars are in proper motion, but, on account of their stupendous distances, it can hardly be detected. When we at a considerable distance view a ship sailing upon the ocean, or an aeroplane suspended in the air, its velocity is so slight that it appears to be only creeping along; but, if we observe it near at hand, its high rate of speed at once becomes apparent. The illusion is caused by the distance; and in the case of the stars the same is infinitely true, for, if we were near them, we might see that they dash along a thousand times as fast as any craft that ploughs the ocean of water or of air.

Sir William Herschel, seeing that the stars are animated with proper motion, and that the sun himself is but a star, propounded the stupendous question as to whether the sun is also in motion like the stars in space beyond. He succeeded in solving this noble

problem and in demonstrating that the sun and his retinue of planets and satellites—the whole stupendous solar system—are sweeping through space with tremendous velocity. He ascertained that our system is being propelled with the velocity of a rifle bullet toward a point in the heavens between the constellations Lyra and Hercules. The velocity of our movement is proportionate to the magnitude of the system, so that it will require more than a million years for the sun and his host to traverse the abyss of space which separates us from those constellations, which, even though we may not possess the means of verifying it, may be tending toward us or swinging at a different rate of speed in some other direction.

Since all the attendants of the sun are ever compelled by his attractive force to maintain their relative distance from him, it is impossible for us, as we participate in the movement, to obtain any idea of our motion by observing the sun or the other members of the system. The method of reasoning which Herschel adopted for the purpose of advancing his theory may be explained by likening our system to a ship and the constellations toward which we are moving to the lighthouses commanding the entrance to a harbor. When the lighthouses are first seen above the horizon, they appear to be near together; but as the ship approaches they become wider and wider, apparently, until at last when the ship enters the harbor they seem no longer to stand side by side, but far apart, guarding the entrance to the port. Thus is it with the solar system: the stars beyond are our beacons, and those in the constellations of Lyra and Hercules seem to be gradually widening, from which we infer

Constellation of Orion.
(Exposure 150 minutes.)

(XX., p. 173.)

that our system is tending toward that point of the universe. How vast the conception which flashed from the master mind of Herschel and gave us this theory of the motion which propels us onward! If the whole solar system is being propelled onward by the magnetic force of a still more powerful constellation, why may not the entire universe as we know it from our observation of the stars, or the infinite universe perceived by our thought and imagination, be conveyed through space with the velocity of light, while our little system and its encircling neighbors swing among the members of infinite expanse!

When we try to comprehend the immensity of space and estimate the number of stars which stud the universe, we find our efforts and calculations necessarily vain. If a great globe occupied all of the universe as we know it, even as far as we can perceive not only with our vision fortified with a powerful telescope, but also as far in the hazy distance as we can extend with the wonderful faculty of our imagination, it would be infinitely less than one drop of sparkling dew compared to the volume of the mighty ocean. How, then, can we compute the area of space, or number the stars of infinity! The task is impossible and the conception vain. Yet, we may grasp some faint idea of the immensity of space and the infinite myriads of stars by pondering the words of the poet:

"But number every grain of sand,
  Wherever salt wave touches land;
Number in single drops the sea,
  Number the leaves on every tree;
Number earth's living creatures, all
  That run, that fly, that swim, that crawl;
Of sands, drops, leaves, and lives, the count

Add up into one vast amount,
And then, for every separate one
Of all those, let a flaming sun
Whirl in the boundless skies, with each
Its massy planets, to outreach
All sight, all thought; for all we see,
Encircled with infinity,
Is but an island."

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